SCIENTIFIC DIALOGUES,

INTENDED FOR THE

INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

NATURAL AND EXPERIMENTAL

PHILOSOPHY

ARE FULLY EXPLAINED.

VOL. VI. OF ELECTRICITY AND GALVANISM.

"Converſation, with the habit of explaining the
"meaning of words, and the ſtructure of common
"domeſtic implements to children, is the ſure and
"effectual method of preparing the mind for the
"acquirement of ſcience."

EDGEWORTH'S PRACTICAL EDUCATION.

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TO

VOL. VI.

ELECTRICITY.

CONTENTS.

GALVANISM.

The Reader is requeſted to correct the following

ERRATA.

Vol. VI. Page 117, line laſt, *for* electrometer, *read* electrophorus.

—— 128, —— 1 from bottom *for* repreſent, *read* repreſenting.

—— 131, —— 3, dele the word *it*.

—— 178, —— 2, Plate 11. Fig. 29, *read* Plate 11. Fig. 30.

CONVERSATION I.

INTRODUCTION.

The early Hiſtory of Electricity.

TUTOR. If I rub pretty briſkly with my hand this ſtick of ſealing wax, and then hold it near any ſmall light ſubſtances as little pieces of paper, the wax will attract them; that is, if the wax be held within an inch or more of the paper, they will jump up and adhere to it.

Charles. They do, and I think I have heard you call this the effects

of electricity, but I do not know what electricity is.

Tutor. It is the cafe with this part of fcience as with many others, we know it only by the effects which it produces. As I have not hitherto, in thefe converfations, attempted to bewilder your minds with ufelefs theories, neither fhall I, in the prefent cafe, attempt to fay what the electrical fluid is: its action is well known; it feems diffufed over every portion of matter with which we are acquainted, and by the ufe of proper methods, it is as eafily collected from furrounding bodies as water is taken from a river.

James. I fee no fluid attaching to the fealing wax when you have rubbed it.

Tutor. You do not ſee the air which you breathe, and with which you are ſurrounded, yet we have ſhown you* that it is a fluid, and may be taken from any veſſel, as certainly, though not with ſo much eaſe, as water may be poured from this glaſs. With the exerciſe of a ſmall degree of patience, you ſhall ſee ſuch experiments as will not fail to convince you that there is as certainly a fluid, which is called the electric fluid, as there are ſuch fluids as water and air.

Charles. Water muſt have been known ſince the creation, and the exiſtence of the air could not long remain a ſecret, but who diſcovered

* See Vol. IV.

the electric fluid, which is not at all evident to the ſenſe either of ſight or feeling?

Tutor. Thales, who lived ſix centuries before the Chriſtian æra, was the firſt who obſerved the electrical properties of amber, and he was ſo ſtruck with the appearances, that he ſuppoſed it to be animated:

> Bright *amber* ſhines on his electric throne,
> And adds ethereal luſtre to his own.
>
> DARWIN.

James. Does amber attract light bodies like ſealing wax?

Tutor. Yes, it does; and there are many other ſubſtances, as well as theſe, that have the ſame power. After Thales, the firſt perſon we read

of that noticed this ſubject was Theophraſtus, who diſcovered that *tourmalin* has the power of attracting light bodies. It does not, however, appear, that the ſubject, though very curious, excited much attention till about 200 years ago, when Dr. Gilbert, an Engliſh phyſician, examined a great variety of ſubſtances, with a view of aſcertaining how far they might or might not be ranked among *electrics*.

Charles. What is meant by an *electric?*

Tutor. Any ſubſtance being excited or rubbed by the hand, or by a woollen cloth, or other means, and has the power of attracting light bodies, is called an *electric.*

James. Is not electricity accompanied with a peculiar kind of light, and with ſparks?

Tutor. It is, of which we ſhall ſpeak more at large hereafter: the celebrated Mr. Boyle is ſuppoſed to have been one of the firſt perſons who got a glimpſe of the electrical light, or who ſeems to have noticed it, by rubbing a diamond in the dark. But he little imagined, at that time, what aſtoniſhing effects would afterwards be produced by the ſame power. Sir Iſaac Newton was the firſt who obſerved that excited glaſs attracted light bodies on the ſide oppoſite to that on which it was rubbed.

Charles. How did he make the diſcovery?

Tutor. Having laid upon the table a round piece of glaſs, about two inches broad, in a braſs ring, by which it was raiſed from the table about the eighth of an inch, and then rubbing the glaſs, ſome little bits of paper which were under it were attracted by it, and moved very nimbly to and from the glaſs.

Charles. I remember ſtanding by a glazier when he was cementing, that is, rubbing over ſome window-lights with oil, and cleaning it off with a ſtiff bruſh and whiting, and the little pieces of whiting under the glaſs, kept continually leaping up and down, as the bruſh moved over the glaſs.

Tutor. That was, undoubtedly, an electrical appearance, but I do

not remember having ever ſeen it noticed by any writer on electricity. A complete hiſtory of this ſcience is given by Dr. Prieſtley, which will, hereafter, afford you much entertainment and intereſting inſtruction. To-morrow we ſhall enter into the practical part of the ſubject; and I doubt not that the experiments in this part of ſcience will be as intereſting as thoſe in any other which you have been ſtudying. The electric light, exhibited in different forms; the various ſigns of attraction and repulſion acting on all bodies; the electric ſhock, and the exploſion of the battery, will give you pleaſure, and excite your admiration.

CONVERSATION II

Of Electric Attraction and Repulsion: of Electrics and Conductors.

TUTOR. You must for a little time, that is, till we exhibit before you experiments to prove it, take it for granted that the earth, and all bodies with which we are acquainted, contain a certain quantity of exceedingly elastic and penetrating fluid, which philosophers call the electric fluid.

Charles. You ſay a certain quantity; is it limited?

Tutor. Like other bodies, it undoubtedly has its limits; this glaſs will hold a certain quantity of water, but if I attempt to pour into it more than that quantity, a part will flow over. So it is with the electric fluid: there is a certain quantity which belongs to all bodies, and this is called their natural quantity, and ſo long as a body contains neither more nor leſs than this quantity, no ſenſible effect is produced.

James. Has this table electricity in it?

Tutor. Yes, and ſo has the inkſtand, and every thing elſe in the room; and if I were to take proper means to put more into it than it

now has, and you were to put your knuckle to it, it would throw it out in the ſhape of ſparks.

James. I ſhould like to ſee this done.

Charles. But what would happen if you ſhould take away ſome of its natural quantity?

Tutor. Why then if you preſented any part of your body to the table, as your knuckle, a ſpark would go from you to the table.

James. But, perhaps, Charles might not have more than his natural ſhare, and in that caſe he could not ſpare any.

Tutor. True; but to provide for this, the earth on which he ſtands would lend him a little to make up for what he parted with to the table.

James. This muſt be an amuſing ſtudy; I think I ſhall like it better than any of the others.

Tutor. Take care that you do not pay for the amuſement before we have done.

Here is a glaſs tube about eighteen inches long, and perhaps an inch or more in diameter; I rub it up and down quickly in my hand, which is dry and warm, and now I will preſent it to theſe fragments of paper, thread and gold-leaf: you ſee they all move to it. That is called electrical *attraction.*

Charles. They jump back again now, and now they return to the glaſs.

Tutor. They are, in fact, alternately attracted and repelled, and

this will laſt ſeveral minutes if the glaſs be ſtrongly excited. I will rub it again, preſent your knuckle to it in ſeveral parts one after another.

James. What is that ſnapping? beſide, I feel ſomething like the pricking of a pin.

Tutor. The ſnapping is occaſioned by little ſparks which come from the tube to your knuckle, and theſe give the ſenſation of pain.

Let us go into a dark room, and repeat the experiment.

Charles. The ſparks are evident enough now, but I do not know where they can come from.

Tutor. The air and every thing is full of the fluid which appears in the ſhape of ſparks; and whatever

be the caufe, which I do not attempt to explain, the rubbing of the glafs with the hand collects it from the air, and having now more than its natural fhare, it parts with it to you, or to me, or to any body elfe that may be near enough to receive it.

James. Will any other fubftance, befides the hand, excite the tube?

Tutor. Yes, many others, and thefe, in this fcience, are called the rubbers; and the glafs tube, or whatever is capable of being thus excited, is called the *electric*.

Charles. Are not all forts of folid fubftances capable of being excited?

Tutor. You may rub this poker, or the round ruler for ever, with-

out obtaining an electric ſpark from them.

James. But you ſaid one might get a ſpark from the mahogany table if it had more than its ſhare.

Tutor. So I ſay you may have ſparks from the poker or ruler if they poſſeſs more than their common ſhare of the electric fluid.

Charles. How do you diſtinguiſh between bodies that can be, and thoſe that cannot be excited?

Tutor. The *former*, as I have told you, are called *electrics*, as the glaſs tube; the latter, ſuch as the poker, the ruler, your body, and a thouſand other ſubſtances are denominated *conductors*.

Charles. I ſhould be glad to know the reaſon of the diſtinction,

becaufe I fhall be more likely to remember it.

Tutor. That is right: when you held your knuckle to the glafs tube, you had feveral fparks from the different parts of it: but if I, by any means, overcharged a conductor, as this poker, all the electricity will come away at a fingle fpark, becaufe the fuperabundant quantity flows inftantaneoufly from every part to that point where it has an opportunity of getting out. I will illuftrate this by an experiment. But firft of all let me tell you, that all *electrics* are called alfo *non-conductors.*

James. Do you call the glafs tube a *non-conductor* becaufe it does not fuffer the electric fluid to pafs from one part of it to another?

Tutor. I do:—ſilk, if dry, is a non-conductor. With this ſkein of ſewing-ſilk I hang the poker or other metal ſubſtance A (Plate I. Fig. 1.) to a hook in the cieling, ſo as to be about twelve inches from it; underneath, and near the extremity, are ſome ſmall ſubſtances, as bits of paper, &c. I will excite the glaſs tube, and preſent it to the upper part of the poker.

Charles. They are all attracted; but now you take away the glaſs they are quiet.

Tutor. It is evident that the electric fluid paſſed from one part of the tube through the poker, which is a conductor, to the paper, and attracted it:—if the glaſs be properly ex-

cited you may take ſparks from the poker.

James. Would not the ſame happen if another glaſs tube were placed in the ſtead of the poker?

Tutor. You ſhall try.—Now I have put the glaſs in the place of the poker, but let me excite the other tube as much as I will, no effect can be produced on the paper:—there are no ſigns of electrical attraction, which ſhows that the electric fluid will not paſs through glaſs.

Charles. What would have happened if any conducting ſubſtance had been uſed, inſtead of ſilk, to ſuſpend the iron poker?

Tutor. If I had ſuſpended the poker with a moiſtened hempen ſtring, the electric fluid would have

all paſſed away through that, and there would have been no (or very trifling) appearances of electricity at the end of the poker.

You may vary theſe experiments till you make yourſelves perfect with regard to the diſtinction between electrics and conductors. Sealing-wax is an electric, and may be excited as well as a glaſs tube, and will produce ſimilar effects. I will give you a liſt of *electrics*, and another of *conductors*, diſpoſed according to the order of their perfection, beginning in each liſt with the moſt perfect of their claſs; thus glaſs is a better *electric* than amber; and gold a better *conductor* than ſilver:

TABLE.

Electrics.	Conductors.
Glaſs of all kinds.	All the metals in the following order:—
All precious ſtones, the moſt tranſparent the beſt.	Gold; ſilver;
Amber.	Copper; platina;
Sulphur.	Braſs; iron;
All reſinous ſubſtances.	Tin; quickſilver;
Wax of all kinds.	Lead.
Silk and Cotton.	The ſemi-metals*.
Dry external ſubſtances, as feathers, wool, and hair.	Metallic ores*.
Paper: loaf ſugar.	Charcoal.
Air when quite dry.	The fluids of an animal body.
Oils and metallic oxides*.	Water, eſpecially ſalt water, and other fluids except oil.
Aſhes of animal and vegetable ſubſtances.	Ice, ſnow.
Moſt hard ſtones.	Moſt ſaline ſubſtances.
	Earthy ſubſtances.
	Smoke; ſteam, and even
	A vacuum.

* This, and other chemical terms, will be explained and familiarly illuſtrated in a work now preparing for the preſs, by the author of the Scientific Dialogues, entitled, Chemiſtry for Children and Young Perſons.

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CONVERSATION III.

Of the Electrical Machine.

TUTOR. I will now explain to you the construction of the electrical machine, and shew you how to use it.

Charles. For what purpose is it used?

Tutor. Soon after the subject of the electric fluid engaged the attention of men of science, they began to contrive the readiest methods of collecting large quantities of it. By

rubbing this ſtick of ſealing-wax I can collect a ſmall portion; if I excite or rub the glaſs tube, I get ſtill more. The object, therefore, was, to find out a machine by which the largeſt quantities can be collected, with as little trouble and expence as may be.

James. You get more electricity from the tube than from the ſealing-wax, becauſe it is five or ſix times as large; by encreaſing the ſize of the tube you would encreaſe the quantity of the electric fluid I ſhould think.

Tutor. That is a natural concluſion. But if you look to the table of electrics which I made out yeſterday, you will ſee that had the wax been as large as the glaſs tube, it

would not have collected ſo much of the electric fluid, becauſe, in its own nature, it is not ſo good an electric.

Charles. By the table, glaſs ſtands as the moſt perfect electric, but there are ſeveral ſubſtances between it and wax, all of which are, I believe, more perfect electrics than wax.

Tutor. They are; electricians, therefore, had no heſitation as to the nature of the ſubſtance: they fixed on glaſs, which being eaſily melted and run, or blown into all ſorts of forms, is, on that account, very valuable.

The moſt common form that is now uſed is that of a glaſs cylinder, from five or ſix inches in diameter

to ten or twelve. Here is one completely fitted up, (Plate I. Fig. 2.) the cylinder A B is about eight inches in diameter, and twelve in length; this I turn round in the frame-work with the handle D C.

James. What is the piece of black ſilk K for?

Tutor. The cylinder would be of no uſe without a rubber you know: on which account you ſee the glaſs pillar R S, which being cemented into a piece of hard wood, is made to ſcrew into the bottom of the machine; on the pillar is a cuſhion, to which is attached the piece of black ſilk.

Charles. And I perceive the cuſhion is made to preſs very hard againſt the glaſs.

Tutor. This preſſure, when the cylinder is turned round faſt, acts preciſely like the rubbing of the tube by the hand, though in a ſtill more perfect manner. I will turn it round.

James. Here is not much ſign of electricity yet.

Tutor. No: the machine is complete, but it has no means of collecting the fluid from the ſurrounding bodies: for you ſee the cuſhion or rubber is fixed on a glaſs pillar, and glaſs will not conduct the electric fluid.

Charles. Nevertheleſs it does, by turning round, ſhow ſome ſigns of attraction.

Tutor. Every body in nature with which we are acquainted poſſeſſes a portion of this fluid, and therefore

the ſigns which are now evident ariſe from the ſmall quantity which exiſts in the rubber itſelf, and the atmoſphere that immediately ſurrounds the machine.

Charles. Would the caſe be different if the rubber were fixed on a conducting ſubſtance inſtead of glaſs?

Tutor. It would; but there is a much eaſier method; I will hang on this braſs chain to the cuſhion at R, which being ſeveral feet long, lies on the table, or on the floor, and this you know is connected, by means of other objects, with the earth, which is the grand reſervoir of the electric fluid. Now ſee the effect of turning round the cylinder: but I muſt make every part of it dry and rather

warm, by rubbing it with a dry warm cloth.

James. It is indeed very powerful! what a crackling noiſe it makes.

Tutor. Shut the window ſhutters.

Charles. The appearance is very beautiful; the flaſhes from the ſilk dart all round the cylinder.

Tutor. I will now bring to the cylinder the tin conductor L, which is alſo placed on a glaſs pillar F N fixed in the ſtand at F.

James. What are the points in the tin conductor for?

Tutor. They are intended to collect the fluid from the cylinder: I will turn the cylinder, and do you hold your knuckle within four or five inches of the conductor.

Charles. The painful ſenſations which theſe ſparks occaſion, prove that the electric fluid is a very powerful agent when collected in large quantities.

Tutor. To ſhow you the nature of conducting bodies, I will now throw another braſs chain over the conductor, ſo that one end of it may lie on the floor: ſee now if you can get any ſparks while I turn the machine.

James. No, I can get none, put my knuckle as near to it as I will:—does it all run away by the chain?

Tutor. It does: a piece of braſs or iron wire would do as well; and ſo would any conducting ſubſtance which touched the conductor with one end, and the floor with the other:

your body would do as well as the chain. Place your hand on the conductor while I turn round the cylinder: and let your brother bring his knuckle near the conductor.

Charles. I can get no ſpark.

Tutor. It runs through James to the earth, and you ſee his body is a conductor as well as the chain. With a very little contrivance I can take ſparks from you or James, as well as you did from the conductor.

James. I ſhould like to ſee how that is done.

Tutor. Here is a ſmall ſtool, having a mahogany top and glaſs legs. If you ſtand on that, and put your hand on the conductor, the electricity will paſs from the conductor to your body.

Charles. Will the glaſs legs prevent it from running from him to the earth?

Tutor. They will: and therefore what he receives from the conductor, he will be ready to part with to any of the ſurrounding bodies, or to you if you bring your hand near enough to any part of him.

James. The ſparks are more painful in coming through my clothes than when I received them on my bare hand.

Tutor. You underſtand, I hope, this proceſs.

Charles. By means of the chain trailing on the ground, the electric fluid is collected from the earth on the glaſs cylinder, which gives it through the points to the conductor;

from this it may be conveyed away again by means of other conductors.

Tutor. Whatever body is supported or prevented from touching the earth, or communicating with it, by means of glaſs or other non-conducting ſubſtances, is ſaid to be *inſulated.* Thus a body ſuſpended on a ſilk line is inſulated, and ſo is any ſubſtance that ſtands on glaſs, or reſin, or wax, provided that theſe are in a dry ſtate, for moiſture will conduct away the electric fluid from any charged body.

CONVERSATION IV.

Of the Electrical Machine.

CHARLES. What is that ſhining ſtuff which I ſaw you put on the rubber yeſterday?

Tutor. It is called *amalgam*: the rubber, by itſelf, would produce a very ſlight excitation; but its power is greatly increaſed by laying upon it a little of this amalgam, which is made of quickſilver, zinc, and tin-foil, with a little tallow or mutton ſuet.

James.. Is there any art required in ufing this amalgam?

Tutor. When the rubber and filk flap are very clean and dry, and in their place, then fpread a little of the amalgam upon a piece of leather, and apply it to the under part of the glafs cylinder, while it is revolving from you; by this means particles of the amalgam will be carried by the glafs itfelf to the lower part of the rubber, and will increafe the excitation.

Charles. I think I once faw a globe inftead of a cylinder for an electrical machine.

Tutor. You might: globes were ufed before cylinders, but the latter are the moft convenient of the two. The moft powerful electrical ma-

chines are fitted with flat plates of glafs. In our experiments we fhall be content with the cylinder, which will anfwer every purpofe of explaining the principles of the fcience.

James. As I was able to conduct the electricity from the tin conductor to the ground, could I likewife act the part of the chain by conducting the fluid from the earth to the cufhion?

Tutor. Undoubtedly: I will take off the chain, and now do you keep your hand on the cufhion while I turn the handle.

James. I fee the machine works as well as when the chain was on the ground.

Tutor. Keep your prefent pofition, but ftand on the ftool with glafs legs; by which means there is now

all communication cut off between the cuſhion and the earth; in other words, the cuſhion is completely inſulated, and can only take from you what electricity it can get from your body. Go, Charles, and ſhake hands with your brother.

Charles. It does not appear that the machine had taken all the electricity from him, for he gave me a ſmart ſpark.

Tutor. You are miſtaken; he gave you nothing, but he took a ſpark from you.

Charles. I ſtood on the ground, I was not electrified; how then could I give him a ſpark?

Tutor. The machine had taken from James the electricity that was in his body, and by ſtanding on the

ſtool, that is, by being inſulated, he had no means of receiving any more from the earth, or any ſurrounding objects; the moment, therefore, you brought your hand near him, the electricity paſſed from you to him.

Charles. I certainly felt the ſpark, but whether it went out of, or entered into my hand, I cannot tell; have I then leſs than my ſhare now?

Tutor. No: what you gave to your brother was ſupplied immediately from the earth. Here is another glaſs-legged ſtool; do you ſtand on this, but at the diſtance of a foot or two from your brother, who ſtill keeps his place. I take the electricity from him by turning the machine, and as he ſtands on the ſtool, he has now leſs than his ſhare. But

you have your natural ſhare, becauſe though you alſo are inſulated, yet you are out of the influence of the machine; extend, therefore, your hand, and give him a part of the electric fluid that is in you.

Charles. I have given him a ſpark.

Tutor. And being yourſelf inſulated, you have now leſs than your natural quantity, to ſupply which you ſhall have ſome from me: give me your hand. Why you draw it back without my touching it.

Charles. I did, but it was near enough to get a ſtrong ſpark from you.

Tutor. When a perſon has *leſs* electricity than his natural ſhare, he is ſaid to be electrified *minus*, or ne-

gatively: but if he has *more* than his natural ſhare, he is ſaid to be electrified *plus*, or poſitively.

James. Then before Charles gave me the ſpark I was electrified minus, and when he had given it me he was minus till he received it from you.

Tutor. That is right. Suppoſe you ſtand on a ſtool and hold the rubber, and Charles ſtand on another ſtool, and touch the prime conductor L while I turn the machine, which of you will be plus, and which minus electrified?

James. I ſhall be minus, becauſe I give to the rubber: and Charles will be plus, becauſe he receives from the conductor what I gave to the rubber, and which is carried by the cylinder to the conductor.

Tutor. You then have lefs than your fhare, and your brother has more than he ought to have. Now if I get another glafs-legged ftool, I can take from Charles what he has too much, and give it to you who have too little.

Charles. Is it neceffary that you fhould be infulated for this purpofe?

Tutor. By being infulated I may perhaps carry back to James the very electricity which paffed from him to you. But if I ftand on the ground, the quantity which I take from you will pafs into the earth, becaufe I cannot, unlefs I am infulated, retain more than my natural fhare.

James. And what is given by you to me is likewife inftantaneoufly fupplied by the earth?

Tutor. It is. Let us make another experiment to fhow that the electric fluid is taken from the earth. Here are fome little balls (Plate I. Fig. 3.) made of the pith of elder: they are put on thread, and being very light, are well adapted to our purpofe.

While the chain is on the cufhion, and I work the machine, do you bring the balls near the conductor by holding the thread at D.

James. They are attracted by it, and now the two balls repel each other, as in the figure x.

Tutor. I ought to have told you, that the upper part D of the

line is ſilk, by which means you know the balls are inſulated, as ſilk is a non-conductor. I take the chain off from the cuſhion, and put it on the conductor, ſo as to hang on the ground, while I turn the machine. Will the balls be affected now, if you hold them to the conductor?

James. No, they are not.

Tutor. Take them to the cuſhion.

Charles. They are attracted and repelled now by being brought near the cuſhion, as they were before, by being carried to the conductor.

Tutor. Yes, and you may now take ſparks from the cuſhion as you did juſt now from the conductor: in both caſes it muſt be evident that

the electric fluid is brought from the earth.

Some machines are furnished with two *conductors*, one of which is connected with the cushion, the other such as we have described. Turn the cylinder, and both conductors will be electrified; but any body which is brought within the influence of these, will be attracted by one of the conductors, and repelled by the other; and, if a chain or wire be made to connect the two together, neither will exhibit any electric appearances: they seem, therefore, to be in opposite states; accordingly electricians say, that the conductor connected with the cushion is negatively electrified, and the other is positively electrified.

CONVERSATION V.

Of Electrical Attraction and Repulsion.

JAMES. What is this large roll of ſealing-wax for?

Tutor. As I mean to explain, this morning, the principles of electrical attraction and repulſion, I have, beſides the electrical machine, brought out for uſe a roll of ſealing-wax, which is about fifteen inches long, and an inch and a quarter in diameter, and the long glaſs tube.

Charles. Are they not both electrics, and capable of being excited?

Tutor. They are; but the electricity produced by exciting them has different or contrary properties.

James. Are there two kind of electricities then?

Tutor. We will ſhow you an experiment before we attempt to give any theory.—I will excite the glaſs tube, and Charles ſhall excite the wax: now do you bring the pith-balls, which are ſuſpended on ſilk (Fig. 3.) to the tube: they are ſuddenly drawn to it, and now they are repelled from one another, and likewiſe from the tube, for you cannot eaſily make them touch it again:—but take them to the excited wax.

James. The wax attracts them very powerfully: now they fall together again, and appear in the same state as they were in before they were brought to the excited tube.

Tutor. Repeat the experiment again and again, because on this two different theories have been formed. One of which is, that there are two electricities, called by some philosophers the *vitreous* or positive electricity; and the *resinous* or negative electricity.

Charles. Why are they called *vitreous* and *resinous*?

Tutor. The word vitreous is Latin, and signifies any *glassy* substance; and the word *resinous* used to denote that the electricity produced by resins, wax, &c. possesses different

qualities from that produced by glaſs.

James. Is it not natural to ſuppoſe that there are two electricities, ſince the excited wax attracts the very ſame bodies that the excited glaſs repels?

Tutor. It may be as eaſily explained, by ſuppoſing that every body, in its natural ſtate, poſſeſſes a certain quantity of the electric fluid, and if a part of it be taken away, it endeavours to get it from other bodies; or if more be thrown upon it than its natural quantity, it yields it readily to other bodies that come within its influence.

Charles. I do not underſtand this.

Tutor. If I excite this glaſs tube, the electricity which it exhibits is ſuppoſed to come from my hand; but if I excite the roll of wax in the ſame way, the effect is, according to this theory, that a part of the electric fluid naturally belonging to the wax, paſſes from it through my hand to the earth: and the wax being ſurrounded by the air, which, in its dry ſtate, is a non-conductor, remains exhauſted, and is ready to take ſparks from any body that may be preſented to it.

James. Can you diſtinguiſh that the ſparks come from the glaſs to the hand; and, on the contrary, from the hand to the wax?

Tutor. No: the velocity with which light, and of courſe the elec-

tric ſpark moves, renders it impoſſible to ſay what courſe it takes; but I ſhall ſhow you other experiments which ſeem to juſtify this theory: and as nature always works by the ſimpleſt means, it ſeems more conſiſtent with her uſual operations, that there ſhould be one fluid rather than two, provided that known facts can be equally well accounted for, by the one as by two.

Charles. Can you account for all the leading facts by either theory?

Tutor. Yes we can.

You ſaw when the pith balls were electrified, they repelled one another. It is a general principle in electricity, that two bodies having more than their natural ſhare of the electric fluid, will repel one another. But if one

have more, and the other lefs than its fhare, they will attract one another.

James. How is this fhown?

Tutor. I will hold this ball, which is infulated, by a filk thread, to the conductor, and do you, Charles, do the fame with the other. Let us now bring them together.

Charles. No, we cannot: they fly from one another.

Tutor. I will hold mine to the infulated cufhion, and you fhall hold yours to the conductor while the machine is turned, now I fufpect they will attract one another.

James. They do indeed.

Charles. The reafon is this; that the cufhion, and whatever is in contact with it, parts with a portion of

its electricity; but the conductor, and the adjoining bodies have more than their ſhare; therefore, the ball applied to the cuſhion, being negatively electrified, will attract the one connected with the conductor, which is poſitively electrified.

Tutor. Here is a tuft of feathers, which I ſtick in a ſmall hole in the conductor: now ſee what happens when I turn the cylinder.

James. They all endeavour to avoid each other, and ſtand erect, in a beautiful manner. Let me take a ſpark from the conductor; now they fall down in a moment.

Tutor. When I turned the wheel they all had more than their ſhare of the electric fluid, and therefore they repelled one another, but the

moment the electricity was taken away, they fell into their natural position. A large plume of feathers, when electrified, grows beautifully turgid, expanding its fibres in all directions, and they collapse when the electricity is taken off.

James. Could you make the hairs on my head repel one another?

Tutor. Yes, that I can. Stand on the glass-legged stool, and hold the chain that hangs on the conductor, in your hand, while I turn the machine.

Charles. Now your hairs stand all an end.

James. And I feel something like cobwebs over my face.

Tutor. There are, however, no cobwebs, but that is a sensation which

a perſon always experiences if he is highly electrified. Hold the pith ball, Charles, near your brother's face.

James. It is attracted in the ſame manner as it was before with the conductor.

Tutor. Hence you may lay it down as a general rule, that all light ſubſtances coming within the influence of an electrified body, are attracted by it, whether it is electrified poſitively or negatively.

Charles. Becauſe they are attracted by the poſitive electricity to receive ſome of the ſuperabundant quantity; and by the negative to give away ſome that they poſſeſs.

Tutor. Juſt ſo: and when they have received as much as they can contain,

they are repelled by the electrified body. The fame thing may be fhown in various ways. Having excited this glafs tube, either by drawing it feveral times through my hand, or by means of a piece of flannel, I will bring it near this fmall feather. See how quickly it jumps to the glafs.

James. It does, and fticks to it.

Tutor. You will obferve, that after a minute or two, it will have taken as much electricity from the tube as it can hold, when it will fuddenly be repelled, and jump to the neareft conductor; upon which it will difcharge the fuperabundant electricity that it has acquired.

James. I fee it is now going to the ground, that being the neareft conductor.

Tutor. I will prevent it by holding the electrified tube between it and the floor. You fee how unwilling it is to come again in contact with the tube: by purfuing I can drive it where I pleafe without touching it.

Charles. That is, becaufe the glafs and the feather are both loaded with the fame electricity?

Tutor. Let the feather touch the ground, or any other conductor, and you will fee that it will jump to the tube as faft as it did before.

I will fufpend this brafs plate, which is about five inches in diameter, to the conductor, and at the diftance of three or four inches below I will place fome fmall feathers, or bits of paper cut into the figures of men and women. They lay very

quiet at present; observe their motions as soon as I turn the wheel.

James. They exhibit a pretty country dance: they jump up to the top plate, and then down again.

Tutor. The same principle is evident in all these experiments. The upper plate has more than its own share of the electric fluid, which attracts the little figures; as soon as they have received a portion of it, they go down to give it to the lower plate; and so it will continue till the upper plate is discharged of its superabundant quantity.

I will take away the plates, and hang a chain on the conductor, the end of which shall lie in several folds in a glass tumbler; if I turn the machine, the electric fluid will run through the chain, and will electrify

the inside of the glass. This done, I turn it quickly over eight or ten small pith balls, which lie on the table.

Charles. That is a very amusing sight; how they jump about: they serve also to fetch the electricity from the glass and carry it to the table.

Tutor. If, instead of the lower metal plate, I hold in my hand a pane of dry and very clean glass, by the corner, the paper figures, or pith balls, will not move, because glass being a non-conducting substance, it has no power of carrying away the superabundant electricity from the plate suspended from the conductor. But if I hold the glass flat in my hand, the figures will be attracted and repelled, which shows that the electric fluid will pass through thin glass.

Take now the following reſults, and commit them to your memory.

(1.) If two inſulated pith balls be brought near the conductor, they will repel each other.

(2.) If an inſulated conductor be connected with the cuſhion, and two inſulated pith balls be electrified by it, they will repel each other.

(3.) If one inſulated ball be electrified by the prime conductor, and another by the conductor connected with the cuſhion, they will attract each other.

(4.) If one ball be electrified by glaſs, and another by wax, they will attract each other.

(5.) If one ball be electrified by a ſmooth, and another by a rough excited glaſs tube, they will attract one another.

CONVERSATION VI.

Of Electrical Attraction and Repulsion.

TUTOR. I will ſhow you another inſtance or two of the effects of electrical attraction and repulſion.

This apparatus (Plate 1. Fig. 4.) conſiſts of three bells ſuſpended from a braſs wire, the two outer ones by ſmall braſs chains; the middle bell, and the two clappers *x x*, are ſuſpended on ſilk. From the middle

bell there is a chain N, which goes to the table, or any other conducting fubftance. The bells are now to be hung by c on the conductor, and the electrical machine to be put in motion.

James. The clappers go from bell to bell, and make very pretty mufic: how do you explain this?

Tutor. The electric fluid runs down the chains *a* and *b* to the bells A, B, thefe having more than their natural quantity, attract the clapper *x x*, which take a portion from A and B, and carry it to the center bell N, and this, by means of the chain, conveys it to the earth.

Charles. Would not the fame effect be produced if the clappers were not fufpended on filk?

Tutor. Certainly not: nor will it be produced if the chain be taken away from the bell N, becauſe then there is no way left to carry off the electric fluid to the earth.

Another amuſing experiment is thus ſhown: Let there be two wires placed exactly one above another, and parallel; the upper one muſt be ſuſpended from the conductor, the other is to communicate with the table: a light image placed between theſe will, when the conductor is electrified, appear like a rope dancer.

This piece of leaf braſs is called the *electric fiſh*, one end is a ſort of obtuſe angle, the other is acute: if the large end be preſented towards an electrified conductor, it will fix to

it, and, from its wavering motion, it will appear to be animated.

This property of attraction and repulsion has led to many inventions of instruments called electrometers.

James. Is not an electrometer a machine to measure the strength of the electricity?

Tutor. Yes; and this is one of the most simple (Plate 1. Fig. 5.) and it depends entirely upon the repulsion which takes place between two bodies in a state of electrification. It consists of a light rod and a pith ball, hanging parallel to the stem, but turning on the centre of a semicircle, so as to keep close to its graduated limb. This is to be placed in a hole on the conductor L, and according as the conductor is more or

leſs electrified, the ball will fly farther from the ſtem.

Charles. If the circular part be marked with degrees, you may aſcertain, I ſuppoſe, pretty accurately, the ſtrength of any given charge.

Tutor. Yes, you may; but you ſee how faſt the air carries away the electricity, it ſcarcely remains a ſingle moment in the place to which it was repelled.—Two pith balls may be ſuſpended parallel to one another, on ſilken threads, and applied to any part of an electrical machine, and they will, by their repulſion, ſerve for an electrometer, for they will repel one another the more, as the machine acts more powerfully.

James. Has this any advantage over the other?

Tutor. It ſerves to ſhow whether the electricity be negative or poſitive; for if it be poſitive, by applying an excited ſtick of ſealing-wax, the threads will fall together again; but if it be negative, excited ſealing-wax, or reſin, or ſulphur, or even a rod of glaſs, the poliſh of which is taken off, will make them recede farther.

We have now, perhaps, ſaid enough reſpecting electrical attraction and repulſion, at leaſt for the preſent; I wiſh you, however, to commit the following reſults to your memory.

I. Bodies that are electrified poſitively repel each other.

II. Bodies that are electrified negatively repel each other.

Charles. Do you mean, that if two bodies have either more or leſs of the

electric fluid than their natural ſhare, they will repel each other if brought ſufficiently near?

Tutor. That is exactly what I mean.

III. Bodies electrified by contrary powers; that is, two bodies, one having more, and the other leſs than its natural ſhare, attract each other very ſtrongly.

IV. Bodies that are electrified attract light ſubſtances which are not electrified.

Theſe are facts which, I truſt, have been made evident to your ſenſes. To-morrow we will deſcribe what is uſually called the Leyden phial.

CONVERSATION VII.

Of the Leyden Phial, or Jar.

TUTOR. I will take away the wires and the ball from the conductor, and then remove the conductor an inch or two farther from the cylinder. If the machine acts strongly, bring an insulated pith ball, that is, you know, one hanging on silk, to the end of the conductor nearest to the glass cylinder.

Charles. It is immediately attracted.

Tutor. Carry it to the other end of the conductor, and ſee what happens.

Charles. It is attracted again, but I thought it would have been repelled.

Tutor. Then as the ball was electrified before, and is ſtill *attracted*, you are ſure that the electricity of the two ends of the conductor are of different names; that is, one is *plus*, and the other *minus*.

James. Which is the poſitive, and which the negative end?

Tutor. That end of the conductor which is neareſt to the cylinder, becomes poſſeſſed of an electricity different from that of the cylinder itſelf.

James. Do you mean, that if the cylinder is poſitively electrified, the end of the conductor next to it is electrified negatively?

Tutor. I do: and this you may ſee by holding an inſulated pith ball between them.

Charles. Yes, it is now very evident, for the ball fetches and carries as we have ſeen it before.

Tutor. What you have ſeen with regard to the conductor, is equally true with reſpect to non-conducting bodies: here is a common glaſs tumbler; if I throw withinſide it a greater portion of electricity than its natural ſhare, and hold it in my hand, or place it on any conducting ſubſtance, as the table, a part of the electric fluid, that naturally belongs to the

outſide, will make its eſcape through my body.

Charles. Let me try this.

Tutor. But you muſt be careful that you do not break the glaſs.

Charles. I will hang the chain on the conductor, and let the other end lie on the bottom of the glaſs, and James will turn the machine.

Tutor. You muſt take care that the chain does not touch the edge of the glaſs, becauſe then the electric fluid will, by that means, run from one ſide of it to the other, and ſpoil the experiment.

James. If I have turned the machine enough, take the chain out, and try the two ſides with the inſulated pith ball.

Charles. What is this! ſomething has pierced through my arms and ſhoulders.

Tutor. That is a trifling electrical ſhock, which you might have avoided, if you had waited for my directions.

Charles. Indeed it was not trifling: I feel it now.

Tutor. This leads us to the Leyden phial: ſo called, becauſe the diſcovery was firſt made at Leyden, in Holland, and by means of a phial or ſmall bottle.

James. Was it found out in the ſame manner as Charles has juſt diſcovered it.

Tutor. Nearly ſo: Mr. Cuneus, a Dutch philoſopher, was holding a glaſs phial in his hand, about half

filled with water, but the ſides above the water, and the outſide was quite dry, a wire alſo hung from the conductor of an electrical machine into the water.

James. Did that anſwer to the chain?

Tutor. Juſt ſo: and, like Charles, he was going to diſengage the wire with one hand, as he held the bottle in the other, and was ſurprized and alarmed by a ſudden ſhock in his arms, and through his breaſt, which he had not the leaſt expected.

Charles. I do not think there was any thing to be alarmed at.

Tutor. The ſhock which he felt was, probably, ſomething ſeverer than that which you have juſt experienced: but the terror was evi-

dently increaſed by its coming ſo completely unexpected.

When M. Muſchenbroeck firſt felt the ſhock, which was by means of a thin glaſs bowl, and very ſlight, he wrote to Reaumur, that he felt himſelf ſtruck in his arms, ſhoulders, and breaſt; ſo that he loſt his breath, and was two whole days before he recovered from the effects of the blow.

Charles. Perhaps he meant the fright?

Tutor. Terror ſeems to have been the effect of the ſhock: for he adds, "I would not take a ſecond ſhock "for the whole kingdom of France."

Mr. Ninkler, an experimental philoſopher, at Leipſic, deſcribes the ſhock as having given him convul-

ſions; a heavineſs in his head, ſuch as he ſhould feel if a large ſtone were on it, and he had reaſon to dread a fever, to prevent which he put himſelf on a courſe of cooling medicines. "Twice," ſays he, "it gave me a bleeding at the noſe, to which I am not inclined, and my wife, whoſe curioſity ſurpaſſed her fears, received the ſhock twice, and found herſelf ſo weak, that ſhe could ſcarcely walk: nevertheleſs, in the courſe of a few days, ſhe received another ſhock, which cauſed a bleeding at the noſe."

James. Is this called the Leyden phial?

Tutor. It is. They are now made in this manner. (Plate 1. Fig. 6.) B A is a glaſs jar, both inſide

and out are covered with tin foil about three parts of the way up, as far as *x*.

Charles. Does the outſide covering anſwer to the hand, and the inſide covering to the water?

Tutor. They do: the piece of wood *z* is placed on the top, merely to ſupport the braſs wire and knob *v*, to the bottom of which hangs a chain that reſts on the bottom of the jar. I will now ſet the jar in ſuch a ſituation that it ſhall be within two or three inches of the conductor while I work the machine.

James. The ſparks fly rapidly from the conductor to the knob.

Tutor. By that means the inſide of the jar becomes charged with a

ſuperabundant quantity of electricity: and as it cannot contain this, without, at the ſame time, driving away an equal quantity from the outſide: the inſide is poſitively electrified, and the outſide is negatively electrified. To reſtore the equilibrium, I muſt make a communication between the outſide and inſide with ſome conducting ſubſtance. That is, I muſt make the ſame ſubſtance touch, at the ſame time, the outſide tin foil, and that which is within, or, which is the ſame thing, another ſubſtance that does touch it.

Charles. The braſs wire touches the inſide: if I, therefore, with one hand touch the knob, and with the

other the outſide covering, will it be ſufficient?

Tutor. It will: but I had rather you would not, becauſe the ſhock will be more powerful than I ſhould with either myſelf or you to experience. Here is a braſs wire with two little balls or knobs *b s* to it. (Plate 1. Fig. 7.) I will bring one of them, as *s* to the outſide, and the other *b*, to the ball *v* on the wire.

James. What a brilliant ſpark, and what a loud noiſe!

Tutor. The electric fluid, that occaſions the light and the noiſe, ran from the inſide of the jar through the wire to *s*, and ſpread itſelf over the outſide.

Charles. Would it have gone through my arms if I had put one hand to the outſide, and touched the wire communicating with the inſide, with the other?

Tutor. It would, and you may believe the ſhock would have been in proportion to the quantity of the fluid collected. The inſtrument I uſed may be called a diſcharging rod: but here is a more convenient one: (Plate I. Fig. 8.) the handle D is ſolid glaſs, faſtened into a braſs ſocket, and the braſs work is the ſame as fig. 7, only by turning on a joint the arms may be opened to any extent.

James. Why is the handle glaſs?

Tutor. Becauſe glaſs being a non-conductor, the electric fluid paſſes

through the braſs work, without affecting the hand; whereas, with the other, a ſmall ſenſation was perceived while I diſcharged the jar.

Charles. Would the jar never diſcharge itſelf?

Tutor. Yes: by expoſure to the air for ſome time, the charge of the jar will be ſilently and gradually diſſipated, for the ſuperabundant electric fluid of the inſide will eſcape, by means of the air, to the outſide of the jar.—But electricians make it a rule never to leave a jar in its charged ſtate.

CONVERSATION VIII.

Of the Leyden Jar: Lane's diſcharging Electrometer, and the Electrical Battery.

CHARLES. In diſcharging the jar yeſterday, I obſerved that when one of the diſcharging rods touched the outſide of the jar, the flaſh and report took place before the other end came in contact with the braſs wire that communicates with the inſide coating.

Tutor. Yes, it acts in the same manner as when you take a spark from the conductor; you do not, for that purpose, bring your knuckle close to the tin.

James. Sometimes, when the machine acts very powerfully, you may get the spark at the distance of several inches.

Tutor. By the same principle, the higher an electrical or Leyden jar is charged, the more easily, or at a greater distance, is it discharged.

Charles. From your experiments it does not seem that it will discharge at so great a distance as that in which a spark may be taken from the conductor.

Tutor. Very frequently a jar will discharge itself, after it has accumu-

lated as much of the electrical fluid as it can contain: that is, the fluid which is thrown on the infide coating will make its way over the glafs, though a non-conductor, on to the outfide coating.

James. In a Leyden jar, after the firft difcharge, you always, I perceive, take another and fmaller one.

Tutor. The tin foil on the jar not being a perfect conductor, the whole quantity of fluid will not pafs at firft from the infide to the out; what remains is called the *refiduum*, and this, in a large jar, would give you a confiderable fhock; therefore, I advife you always, in difcharging an electrical jar, to take away the refiduum before you venture to remove

the apparatus. I will now deſcribe an electrometer, which depends, for its action, on the principles we have been deſcribing.

Charles. Do you mean upon the jar's diſcharging before the outſide and inſide coating are actually brought into contact?

Tutor. I do: (Plate I. Fig. 10.) The arm D is made of glaſs, and proceeds from a ſocket on the wire of the electrical jar F. To the top of the glaſs arm is cemented another braſs ſocket E, through which a wire with balls B and C at each end will ſlide backwards and forwards.

James. So that it may be brought to any diſtance from the ball A, which is on the wire connected with the inſide of the jar?

Tutor. Juſt ſo. When the jar F is ſet either in contact, or very near the conductor, as is repreſented in the figure, and the ball B is ſet at the diſtance of the eighth of an inch from the ball A, let a wire C K be fixed between the ball C and the outſide coating of the jar. Then as ſoon as the machine is worked, the jar cannot be charged beyond a certain point; for when the charge is ſtrong enough to paſs from A to the ball B, the diſcharge will take place, and the electric fluid collected in the inſide will paſs through the wire C K to the outſide coating.

Charles. If you remove the balls to a greater diſtance from one another, will a ſtronger charge be required before the fluid can paſs from

the inside of the jar to the ball B of the electrometer?

Tutor. Certainly: and therefore the discharge will be much stronger. This machine is called Lane's Discharging Electrometer, from the name of the person who invented it. It is very useful in applying the electric shock to medical purposes, as we shall see hereafter.

This box contains nine jars or Leyden phials, (Plate I. Fig. 9.) the wires which proceed from the inside of each three of these jars, are screwed or fastened to a common horizontal wire E, which is knobbed at each extremity, and, by means of the wires F F, the inside coatings of 3 or 6, or the whole 9 may be connected.

James. Is it a common box in which the jars are placed?

Tutor. The inſide of the box is lined with tin foil; ſometimes very thin tin-plates are uſed, for the purpoſe of connecting, more effectually, the outſide coatings of all the jars.

Charles. What is the hook on one of the ſides of the box for?

Tutor. To this hook is faſtened a ſtrong wire, which communicates with the inſide lining of the box, and, of courſe, with the outſide coating of the jars. And, as you ſee, to the hook a wire is alſo faſtened, which connects it with one branch of the diſcharging rod.

James. Is there any particular art to be uſed in charging a battery?

Tutor. No: the beſt way is, to

bring a chain, or piece of wire, from the conductor to one of the balls on the rods that reſt upon the jars: and then ſet the machine to work. The electric fluid paſſes from the conductor to the inſide of all the jars, till it is charged ſufficiently high for the purpoſe. Great caution, however, muſt be uſed when you come to make experiments with a battery, for fear of an accident, either to yourſelf, or to ſpectators.

Charles. Would a ſhock from this be attended with any bad conſequences?

Tutor. Yes: very ſerious accidents may happen from the electricity accumulated in a large battery, and even with a battery ſuch as is repreſented in the plate, which is one

of the ſmalleſt made; a ſhock may be given, which, if paſſed through the head, or other vital parts of the body, may be attended with very miſchievous effects.

James. How do you know when the battery is properly charged?

Tutor. The quadrant electrometer (Plate I. Fig. 5.) is the beſt guide, and this may be fixed either on the conductor, or upon one of the rods of the battery. But if it is fixed on the battery, the ſtem of it ſhould be of a good length, not leſs than 12 or 15 inches.

Charles. How high will the index ſtand when the battery is charged?

Tutor. It will ſeldom riſe ſo high as 90°, becauſe a machine, under the

moſt favorable circumſtances, cannot charge a battery ſo high, in proportion, as a ſingle jar. You may reckon that a battery is well charged when the index riſes as high as 60° or between that and 70°.

James. Is there no danger of breaking the jars when the battery is very highly charged?

Tutor. Yes, there is; and if one jar be cracked, it is impoſſible to charge the others, till the broken one be removed: to prevent accidents, it is recommended not to diſcharge a battery through a good conductor, except the circuit is at leaſt five feet long.

Charles. Do you mean the wire ſhould be ſo long?

Tutor. Yes, if you paſs the charge through that; but you may carry it through any conductor.

Before a battery is uſed, the uncoated part of the jars muſt be made perfectly clean and dry, the ſmalleſt particles of duſt will carry away the electric fluid. And after an exploſion, always connect the wire from the hook, with the ball, to prevent any reſiduum.

CONVERSATION IX.

Experiments made with the Electrical Battery.

TUTOR. I will now ſhow you ſome experiments with this large battery: to perform theſe in perfect ſafety, I muſt beg you to ſtand a good diſtance from it; this will prevent accidents.

Example I. I take this quire of writing paper, and place it againſt the hook or wire that comes out of the box; and when the battery is

charged, I put one ball of the diſcharging rod to a knob of one of the wires F, and bring the other knob to that part of the paper that ſtands againſt the wire, proceeding from the box: you ſee what a hole it has made through every ſheet of the paper. Smell the paper where the perforation is.

Charles. It ſmells like ſulphur.

Tutor. Or more like phoſphorus: you obſerve, in this experiment, that the electric fluid paſſed from the inſide of the jars through the conducting rod and paper, to the outſide.

James. Why did it not paſs through the paper, in the ſame manner as it paſſed the braſs diſcharging rod, in which it made no hole?

Tutor. Paper is a non-conducting ſubſtance, but braſs is a conductor: through the latter it paſſes without any reſiſtance, and in its endeavour to get to the inſide of the box, it burſt the paper as you ſee: the ſame thing would have happened had there been twice or thrice as much paper. The electric fluid of a ſingle jar will pierce through many ſheets of paper.

Charles. Would it ſerve any other non-conducting ſubſtance in the ſame manner?

Tutor. Yes, it will even break a thin piece of glaſs, or of reſin, or of ſealing-wax, if they be interpoſed between the diſcharging rod and the outſide of the coating of the battery.

Ex. II. Place a piece of loaf ſugar in the ſituation in which the quire of paper was juſt now, the ſugar will be broken, and in the dark it will appear beautifully illuminated, and remain ſo for many ſeconds of time.

Ex. III. Let the ſmall piece of wire, proceeding from the hole in the box, be laid on one ſide of a plate, containing ſome ſpirits of wine, and, on the oppoſite ſide of the plate, bring one of the knobs of the diſcharging-rod, while the other is carried to the wires connected with the inſide of the jars.

Charles. Then the electric fluid will have a paſſage through the ſpirit?

Tutor. It will ſet it on fire inſtantly.

Ex. IV. Take two ſlips of common window-glaſs, about four inches long, and one inch broad; put a ſlip of gold leaf between the glaſſes, leaving a ſmall part of it out at each end, then tie the glaſſes together, or preſs them with a heavy weight, and ſend the charge of the battery through it, by connecting one end of the glaſs with the outſide of the jars, and bringing the diſcharging rod to the other end, and to the wires of the inſide of the battery.

James. Will it break the glaſs?

Tutor. It probably will; but whether it does or not, the gold leaf will be forced into the pores of the glaſs, ſo as to appear like glaſs ſtained with gold, which nothing can waſh away.

Ex. V. If the gold leaf be put between two cards, and a ſtrong charge paſſed through it, it will be completely fuſed or melted, the marks of which will appear on the card.

This inſtrument (Plate I. Fig. 11.) called an univerſal diſcharger, is very uſeful for paſſing charges through many ſubſtances. B B are glaſs pillars cemented into the frame A. To each of the pillars is cemented a braſs cap, and a double joint for horizontal and vertical motions; on the top of each joint is a ſpring tube, which holds the ſliding wires C *x*, C *x*, ſo that they may be ſet at various diſtances from each other, and turned in any direction; the extremities of the wires are pointed, but with ſcrews, at about half an inch

from the points, to receive balls. The table E D, inlaid with a piece of ivory, is made to move up and down in a ſocket, and a ſcrew faſtens it to any required height. The rings C C are very convenient for fixing a chain or wire to them, which proceeds from the conductor.

Charles. Do you lay any thing on the ivory, between the balls, when you want to ſend the charge of a battery through it?

Tutor. Yes; and by drawing out the wires, the balls may be ſeparated to any diſtance leſs than the length of the ivory. The little figure H (Plate I. Fig. 12.) repreſents a preſs, which may be ſubſtituted in the place of the table E D: it conſiſts of two flat pieces of mahogany,

which may be brought together by ſcrews.

James. Then inſtead of tying the ſlips of glaſs together in Ex. 4. you might have done it better by making uſe of the preſs?

Tutor. I might; but I was willing to ſhow you how the thing might be done if no ſuch apparatus as this were at hand. The uſe of the table and preſs, which, in fact, always go together, is for keeping ſteady all deſcriptions of bodies through which the charge of a ſingle jar, or any number of which a battery conſiſts, is to be conveyed. We will now proceed with the experiments.

Ex. VI. I will take the knobs from the wires of the Univerſal Diſcharger, and having laid a piece

of very dry writing-paper on the table E, I place the points of the wires at an inch or more from one another; then, by connecting one of the rings c with the outside wire or hook of the battery, and bringing the discharging rod from the other ring c to one of the knobs of the battery, you will see that the paper will be torn to pieces.

Ex. VII. The experiment which I am now going to make, you must never attempt by yourselves: I put a little gunpowder in the tube of a quill, open at both ends, and insert the pointed extremities of the two wires in it, so as to be within a quarter of an inch or less from each other. I now send the charge of the battery

through it, and the gunpowder, you fee, is inftantly inflamed.

Ex. VIII. Here is a very flender wire, not a hundredth part of an inch in diameter, which I connect with the wires of the difcharger, and fend the charge of a battery through it, which will completely melt it, and you now perceive the little globules of iron inftead of the thin wire.

Charles. Will other wires befides iron be melted in the fame manner?

Tutor. Yes, if the battery be large enough, and the wires fufficiently thin, the experiment will fucceed with them all; even with a fingle jar, if it be pretty large, very flender wire may be fufed. But the charges of batteries have been ufed to deter-

mine the different conducting powers of the feveral metals.

James. If the charge is not ftrong enough to melt the wire, will it make it red hot?

Tutor. It will: and when the experiment is properly done, the courfe of the fluid may be difcerned by its effects: for if the wire is about three inches long, it will be feen that the end of it, which is connected with the infide of the battery, is red-hot firft, and the rednefs proceeds towards the other.

Charles. That is a clear proof that the fuperabundant electricity accumulated in the infide is carried to the outfide of the jars.

Tutor. Ex. IX. We fhall hereafter difcufs the fubject of mag-

netiſm: but by diſcharging the battery through a ſmall ſewing needle, it will become magnetic, that is, if the needle be accurately ſuſpended on a ſmall piece of cork in a baſon of water, one end will, of itſelf, point to the north, and the other to the ſouth.

Ex. X. I will lay this chain on a ſheet of writing-paper, and ſend the charge of the battery through the chain; and you will ſee black marks will be left on the paper in thoſe places where the rings of the chain touch each other.

Ex. XI. Place a ſmall piece of very dry wood between the balls of the univerſal diſcharger, ſo that the fibres of the wood may be in the direction of the wires, and paſs the charge of the battery through them,

and the wood will be torn in pieces. The points of the wires being run into the wood, and the ſhock paſſed thro' them, will effect the ſame thing.

Ex. XII. Here is a glaſs tube, open at both ends, ſix inches long, and a quarter of an inch in diameter. Theſe pieces of cork, with wires in them, exactly fit the ends of the tube. I put in one cork, and fill the tube with water, then put the other cork in, and puſh the wires ſo that they nearly touch, and paſs the charge of the battery through them, you ſee the tube is broken, and the water diſperſed in every direction *.

* To prevent accidents, a wire cage, ſuch as is uſed in ſome experiments on the air-pump, ſhould be put over the tube before the diſcharge is made; young perſons ſhould not attempt this experiment by themſelves.

Charles. If water is a good conductor, how is it that the charge did not run through it without breaking the tube?

Tutor. The electric fluid, like common fire, converts the water into an highly elastic vapour, which, occupying very suddenly a much larger space than the water, bursts the tube before it can effect any means of escape.

CONVERSATION X.

Of the Electric Spark, and Miscellaneous Experiments.

TUTOR. I wish you to observe some facts connected with the electric spark. By means of the wire inserted in this ball, I fix it to the end of the conductor, and bring either another brass ball, or my knuckle to it, and if the machine act pretty powerfully, a long, crooked, brilliant spark will pass between the two balls, or between the knuckle and ball. If the conductor

is negative, it receives the ſpark from the body; but if it is poſitive, the ball or the knuckle receives the ſpark from the conductor.

Charles. Does the ſize of the ſpark depend at all on the ſize of the conductor?

Tutor. The longeſt and largeſt ſparks are obtained from a large conductor, provided the machine act very powerfully. When the quantity of electricity is ſmall, the ſpark is ſtraight; but when it is ſtrong, and capable of ſtriking at a greater diſtance, it aſſumes what is called a zig-zag direction.

James. If the electric fluid is fire, why does not the ſpark, which excites a painful ſenſation, burn me, when I receive it on my hand?

Tutor. Ex. I. I have ſhown you that the charge from a battery will make iron wire red hot, and inflame gunpowder. Now ſtand on the ſtool with glaſs legs, and hold the chain from the conductor with one hand. Do you, Charles, hold this ſpoon which contains ſome ſpirit of wine, to your brother, while I turn the machine, and a ſpark taken from his knuckle, if large, will ſet fire to the ſpirit.

Charles. It has indeed: did you do nothing with the ſpirit?

Tutor. I only made the ſilver ſpoon pretty warm before I put the ſpirit into it.

Ex. II. If a ball of box-wood be placed on the conductor inſtead of

the braſs ball, a ſpark taken from it will be of a fine red colour.

Ex. III. An ivory ball placed on the conductor will be rendered very beautiful and luminous if a ſtrong ſpark be taken through its center.

Ex. IV. Sparks taken over a piece of ſilver leather appear of a green colour, and over gilt leather of a red colour.

Ex. V. Here is a glaſs tube, (Plate I. Fig. 13.) round which, at ſmall diſtances from each other, pieces of tin foil are paſted in a ſpiral form from end to end; this tube is encloſed in a larger one, fitted with braſs caps at each end, which are connected with the tin foil of the inner tube.—I hold one end A in my hand, and while one of you turn

the machine, I will preſent the other end B to the conductor, to take ſparks from it: but firſt ſhut the window ſhutters.

Charles. This is a very beautiful experiment.

Tutor. The beauty of it conſiſts in the diſtance which is left between the pieces of tin foil, and by increaſing the number of theſe diſtances, the brilliancy is very much heightened.

Ex. VI. The following is another experiment of the ſame kind: Here is a word, with which you are acquainted (Plate II. Fig. 14.) made on glaſs, by means of tin foil paſted on glaſs, fixed in a frame of baked wood. I hold the frame in my hand at H, and preſent the ball G to the

conductor, and at every confiderable fpark the word is beautifully illuminated.

Ex. VII. A piece of fponge filled with water, and hung to a conductor, when electrified in a dark room, exhibits a beautiful appearance.

Ex. VIII. This bottle is charged: if I bring the brafs knob that ftands out of it, to a bafin of water which is infulated, it will attract a drop; and, on the removal of the bottle, it will affume a conical fhape, and if brought near any conducting fubftance, it will fly to it in luminous ftreams.

Ex. IX. Place a drop of water on the conductor, and work the machine, the drop will afford a long

ſpark, aſſume a conical figure, and carry ſome of the water with it.

Ex. X. On this wire I have fixed a piece of ſealing-wax, and having fixed the wire into the end of the conductor, I will light the wax, and the moment the machine is worked, the wax will fly off in the fineſt filaments imaginable.

Ex. XI. I will wrap ſome cotton-wool round one of the knobs of my diſcharging rod, and fill the wool with finely bruiſed reſin; I now diſcharge a Leyden jar, or a battery in the common way, and the wool is inſtantly in a blaze. The covered knob muſt touch the knob of the jar, and the diſcharge ſhould be effected as quickly as poſſible.

You will remember, that the electric fluid always chuses the nearest road, and the best conductors to travel by; in proof of which take the following experiment:—

Ex. XII. With this chain I make a sort of W, (Plate 1. Fig. 15.) the wire *w* touches the outside of a charged jar, and the wire *x* is brought to the knob of the jar, and in the dark a brilliant W is visible. But if the wire *w* is continued to *m*, the electric fluid takes a shorter road to *x*, and, of course, only half of the W is seen, viz. that part marked *m z y*: but if, instead of the wire *w m*, a dry stick be laid in its place, the electric matter will prefer a longer circuit, rather than go through a bad

conductor, and the whole W will be illuminated.

Ex. XIII. Here is a two ounce phial half full of sallad oil, through the cork is passed a piece of slender wire, the end of which, within the phial, is so bent as to touch the glass just below the surface of the oil. I place my thumb opposite the point of the wire in the bottle, and in that position take a spark from the charged conductor. You observe that the spark, to get to my thumb, has actually perforated the glass. In the same way I can make holes all round the phial.

Charles. Would the experiment succeed with water instead of oil?

Tutor. No, it would not.

James. At any rate we fee the courfe of the electric fluid in this experiment, for the fpark comes from the conductor down the wire, and through the glafs to the thumb.

Tutor. Its direction is, however, better fhown in this way.

Ex. XIV. At that end of the conductor which is fartheft from the machine, I fix a brafs wire about fix inches long, having a fmall brafs ball on its extremity. To this ball, when the machine is at work, I hold the flame of a wax taper.

Charles. The flame is evidently blown from the ball in the direction of the electric fluid; it has a fimilar effect to the blaft of a pair of bellows.

Ex. XV. I will fix a pointed wire upon the prime conductor, with the

point outward, and another like wire upon the inſulated rubber:—ſhut the window ſhutter, and I will work the machine:—now obſerve the points of the two wires.

James. They both are illuminated, but differently. The point on the conductor ſends out a ſort of bruſh of fire, but that on the rubber is illuminated with a ſtar.

Tutor. You ſee then the difference between the poſitive and negative electricity.

CONVERSATION XI.

Miſcellaneous Experiments: of the Electrophorus; of the Electrometer, and the Thunder Houſe.

TUTOR. I ſhall proceed this morning with ſome other experiments on the electrical machine.

Ex. I. Here are two wires, one of which is connected with the outſide of this charged Leyden jar, the other is ſo bent as eaſily to touch the knob of the jar. The two ſtrait ends

I bring within the diſtance of the tenth of an inch of one another, and preſs them down with my thumb, and in this poſition, having darkened the room, I diſcharge the jar: do you look upon my thumb.

Charles. It was ſo tranſparent that I think I even ſaw the bone of the thumb: but did it not hurt you very much?

Tutor. With attention, you might obſerve the principal blood veſſels, I believe, and the only inconvenience that I felt was a ſort of tremor in my thumb, which is by no means painful. Had the wires been at double the diſtance, the ſhock would have probably made my thumb the circuit, which muſt have cauſed a more powerful and unpleaſant ſenſation,

but being ſo cloſe, the electric fluid leaped from one wire to the other, and during this paſſage it illuminated my thumb, but did not go through it.

Ex. II. If, inſtead of my thumb, a decanter full of water, having a flat bottom, were placed on the wires, and the diſcharge made, the whole of the water will be beautifully illuminated.

Ex. III. This ſmall pewter bucket is full of water, and I ſuſpend it from the prime conductor, and put in a glaſs ſyphon, with a bore ſo narrow that the water will hardly drop out. See what will happen when I work the machine, but firſt make the room dark.

James. It runs now in a full ſtream, or rather in ſeveral ſtreams, all of which are illuminated.

Tutor. Ex. IV. If the knob *a*, (Plate II. Fig. 16.) communicate with the outſide of a charged Leyden jar, and the knob *b* with the inſide coating, and each be held about two inches from the lighted candle *x*, and oppoſite to one another, the flame will ſpread towards each, and a diſcharge will be made through it: this ſhows the conducting power of flame.

This inſtrument, (Plate II. Fig. 17.) which conſiſts of two circular plates, of which the largeſt B is about fifteen inches in diameter, and the other A 14 inches, is called an *electrometer.*

The *under* plate B is made of glaſs, or ſealing-wax, or of any other non-conducting ſubſtance; I have made one with a mixture of pitch and chalk boiled together. The upper plate A is ſometimes made of braſs, and ſometimes of tin plate, but this is of wood, covered very neatly with tin foil: *x* is a glaſs handle fixed to a ſocket, by which the upper plate is removed from the under one.

Charles. What do you mean by an electrophorus?

Tutor. It is, in fact, a ſort of ſimple electrical machine, and is thus uſed. Rub the lower plate B with a fine piece of new flannel, or with rabbits', or hares', or cats' ſkin,

and when it is well excited, place upon it the upper plate A, and put your finger on the upper plate; then remove this plate by the glaſs handle *x*, and if you apply your knuckle, or the knob of a coated jar, you will obtain a ſpark. This operation may be repeated many times without exciting again the under plate.

James. Can you charge a Leyden jar in this way?

Tutor. Yes, it has been done, and by a ſingle excitation, ſo as to pierce a hole through a card.

Here is another kind of electrometer, (Plate II. Fig. 18.) which is by far the moſt ſenſible that has been yet invented; that is, it is capable of diſ-

covering the ſmalleſt quantities of electricity. A is a glaſs jar, B the cover of metal, to which is attached two pieces of gold leaf x, or two pith balls ſuſpended on threads; on the ſides of the glaſs jar are two narrow ſtrips of tin foil.

Charles. How is this inſtrument uſed?

Tutor. Any thing that is electrified is to be brought to the cover, which will cauſe the pieces of gold leaf, or pith balls, to diverge; and the ſenſibility of this inſtrument is ſo great, that the bruſh of a feather, the throwing of chalk, hair-powder, or duſt, againſt the cap B, evinces ſtrong ſigns of electricity.

Ex. V. Place on the cap B a little pewter, or any other metallic cup,

having ſome water in it; then take from the fire a live cinder, and put it in the cup, and the electricity of vapour is very admirably exhibited.

A thunder cloud paſſing over this inſtrument, will cauſe the gold leaf to ſtrike the ſides at every flaſh of lightning.

Ex. VI. I will excite this ſtick of ſealing wax, and bring it to the cover B,—you ſee how often it cauſes the gold leaf to ſtrike againſt the ſides of the glaſs.

James. Are the ſlips of tin foil intended to carry away the electric fluid communicated by the objects preſented to the cap B?

Tutor. They are; and by them the equilibrium is reſtored.

CONVERSATION XII.

Of Atmoſpherical Electricity.

CHARLES. You ſaid yeſterday, that the electrometer was affected by thunder and lightning: are lightning and electricity ſimilar?

Tutor. They are, undoubtedly, the ſame fluid; and that they are the ſame was diſcovered by Dr. Franklin more than half a century ago.

James. How did he aſcertain this fact?

Tutor. He was led to form the theory, from obſerving the power which uninſulated *points* have in drawing of the electricity from bodies. And having made his ſyſtem, he was waiting for the erection of a ſpire, in Philadelphia, to carry his views into execution, when it occurred to him that a boy's kite would anſwer his purpoſe better than a ſpire. He therefore prepared a kite, and having raiſed it, he tied to the end of the ſtring a ſilken cord, by which the kite was completely inſulated. At the junction of the two ſtrings he faſtened a key as a good conductor, in order to take ſparks from it.

Charles. Did he obtain any ſparks?

Tutor. One cloud, which appeared like a thunder-cloud, paſſed without

any effect; ſhortly after, the looſe threads of the hempen ſtring ſtood erect, in the ſame manner as they would if the ſtring had been hung on an electrified inſulated conductor. He then preſented his knuckle to the key, and obtained an evident ſpark. Others ſucceeded before the ſtring was wet, but when the rain had wetted the ſtring, he collected the electricity very plentifully:

—— Led by the phoſphor light, with daring tread,
Immortal Franklin ſought the fiery bed;
Where, nurſed in night, incumbent tempeſt ſhrouds
The ſeeds of thunder in circumfluent clouds,
Beſieged with iron points his airy cell,
And pierced the monſter ſlumbering in the ſhell.

DARWIN.

James. Could I do ſo with our large kite?

Tutor. I hope you will not try to raiſe your kite during a thunder ſtorm, becauſe, without very great care, it may be attended with the moſt ſerious danger: your kite is, however, quite large enough, being four feet high, and two feet wide; every thing depends on the ſtring, which, according to Mr. Cavallo, who has made many experiments on the ſubject, ſhould be made of two thin threads of twine, twiſted with a copper thread. And to Mr. Cavallo's work on electricity, vol. II. ſuch perſons as are deſirous of raiſing kites, for electrical purpoſes, ſhould be referred, in which they will find ample inſtruction.

Charles. How do the conductors, which I have seen fixed to various buildings, act in dispersing lightning?

Tutor. You know how easy it is to charge a Leyden jar: but if, when the machine is at work, a person hold a point of steel, or other metal, near the conductor, the great part of the fluid will run away by that point instead of proceeding to the jar. Hence it was concluded that pointed rods would silently draw away the lightning from clouds passing over any building.

James. Is there not a particular method of fixing them?

Tutor. Yes: the metallic rod must reach from the ground, or the nearest piece of water, to a foot or two above the building it is intended to protect,

and the iron rod ſhould come to a fine point: ſome electricians recommend that the point ſhould be of gold, to prevent its ruſting.

Charles. What effects would be produced if lightning ſhould ſtrike a building without a conductor?

Tutor. That may be beſt explained by informing you of what happened, many years ago, to St. Bride's church. The lightning firſt ſtruck the weather-cock, from thence deſcending in its progreſs, it beat out a number of large ſtones of different heights, ſome of which fell upon the roof of the church, and did great damage to it. The miſchief done to the ſteeple was ſo conſiderable, that eighty-five feet of it was obliged to be taken down.

James. The weather-cock was probably made of iron, why did not that aƈt as a conduƈtor?

Tutor. Though that was made of iron, yet it was completely inſulated by being fixed in ſtone, that had become dry by much hot and dry weather. When therefore the lightning had taken poſſeſſion of the weather-cock, by endeavouring to force its way to another conduƈtor, it beat down whatever ſtood in its way.

Charles. The power of lightning muſt be very great.

Tutor. It is irreſiſtible in its effeƈts; the following experiment will illuſtrate what I have been ſaying.

Ex. I. A is a board, (Plate II. Fig. 19.) repreſents the gable end of a houſe; it is fixed on another

board B: *a*, *b*, *c*, *d*. is a ſquare hole to which a piece of wood is fitted; *a d* repreſents a wire fixed diagonally on the wood *a*, *b*, *c*, *d*; *x b* terminated by a knob *x*, repreſents a weather-cock, and the wire *c z* is fixed to the board A.

It is evident, that in the ſtate in which it is drawn in the figure, there is an interruption in the conducting rod; accordingly, if the chain *m* is connected with the outſide of a Leyden phial, and then that phial is diſcharged through *x*, by bringing one part of the diſcharging rod to the knob of the Leyden phial, and the other to within an inch or two of *x*, the piece of wood *a*, *b*, *c*, *d*, will be thrown out with violence.

James. Are we to underſtand by this experiment that if the wire *x b* had been continued to the chain, that the electric fluid would have run through it without diſturbing the looſe board?

Tutor. Ex. II. Juſt ſo; for if the piece of wood be taken out, and the part *a* be put to the place *b*, then *d* will come to *c*, and the conducting rod will be compleat, and continued from *x* through *a* and *d* to *z*, and now the phial may be diſcharged as often as you pleaſe, but the wood will remain in its place, becauſe the electric fluid runs through the wire to *z*, and makes its way by the chain to the outſide of the phial.

Charles. Then if *x* be ſuppoſed the weather-cock of the church, the

lightning having overcharged this, by its endeavours to reach another conductor, as *c z*, it forced away the stone or stones represented by *a b c d?*

Tutor. That is what I meant to convey to your minds by the first experiment; and the second shows very clearly, that if an iron rod had gone from the weathercock to the ground, without interruption, it would have conducted away the electricity silently, and without doing any injury to the church.

James. How was it that all the stones were not beat down?

Tutor. Because, in its passage downwards, it met with many other conductors. I will read part of what Dr. Watson says on this fact, who examined it very attentively:—

"The lightning," ſays he, "firſt took a weathercock, which was fixed at the top of the ſteeple, and was conducted without injuring the metal or any thing elſe, as low as where the large iron bar or ſpindle which ſupported it terminated, there the metallic communication ceaſing, part of the lightning exploded, cracked, and ſhattered the obeliſk, which terminated the ſpire of the ſteeple, in its whole diameter, and threw off, at that place, ſeveral large pieces of Portland ſtone. Here it likewiſe removed a ſtone from its place, but not far enough to be thrown down. From thence the lightning ſeemed to have ruſhed upon two horizontal iron bars, which were placed within the building croſs each other. At the end of one of theſe

iron bars, it exploded again, and threw off a confiderable quantity of ftone. Almoft all the damage was done where the ends of the iron bars had been inferted into the ftone, or placed under it; and, in fome places, its paffage might be traced from one iron bar to another."——

The thunder holds his black tremendous throne:
From cloud to cloud the rending lightnings rage;
Till, in the furious elemental war
Diffolved, the whole precipitated mafs
Unbroken floods and folid torrents pours.

THOMSON.

CONVERSATION XIII.

On Atmoſpheric Electricity: of Falling Stars: of the Aurora Borealis: of Water-ſpouts and Whirlwinds: of Earthquakes.

CHARLES. Does the air always contain electricity?

Tutor. Yes, and it is owing to the electricity of the atmoſphere that we obſerve a number of curious and intereſting phenomena, ſuch as falling ſtars; the aurora borealis, or

northern lights; the ignis fatuus, or Will-with-the-wifp.

James. I have frequently feen what people call falling ftars, but I never knew that they were occafioned merely by electricity.

Tutor. Thefe are feen chiefly in clear and calm weather: it is then that the electric fluid is probably not very ftrong, and paffing through the air it becomes vifible in particular parts of its paffage, according to the conducting fubftances it may meet with. One of the moft ftriking phenomena of this kind is recorded by Signior Beccaria:—As he was fitting with a friend in the open air, an hour after fun-fet, they faw a falling, or as it is fometimes called, a fhooting ftar, directing its courfe to-

wards them, growing, apparently, larger and larger, till it diſappeared not far from them, and diſappearing it left their faces, hands, and cloaths, with the earth and neighbouring objects, ſuddenly illuminated with a diffuſed and lambent light, attended with no noiſe at all.

Charles. But how did he know that this was only the effect of electricity?

Tutor. Becauſe he had previouſly raiſed his kite, and found the air very much charged with the electric matter: ſometimes he ſaw it advancing to his kite like a falling ſtar; and ſometimes he ſaw a kind of glory round it, which followed it as it changed its place.

James. Since lofty objects are exposed to the effects of lightning, or the electric fluid, do not the tall masts of ships run considerable risk of being struck by it?

Tutor. Certainly: we have many instances recorded of the mischief done to ships. One of which is related in the Philosophical Transactions; it happened on board the Montague, on the 4th of November, 1748, in lat. 42° 48′ and 9° 3′ west longitude, about noon. One of the quarter masters desired the master of the vessel to look to the windward, when he observed a large ball of blue fire, rolling apparently on the surface of the water, at the distance of three miles from them: it rose almost perpendicular when it was with-

in forty or fifty yards from the main chains of the ſhip, it then went off with an exploſion, as if an hundred cannon had been fired at one time, and left ſo great a ſmell of ſulphur, that the ſhip ſeemed to contain nothing elſe. After the noiſe had ſubſided, the main-top-maſt was found ſhattered to pieces, and the maſt itſelf was rent quite down to the keel. Five men were knocked down, and one of them greatly burnt by the exploſion.

Charles. Did it not ſeem to be a very large ball to have produced ſuch effects?

Tutor. Yes: the perſon who noticed it ſaid it was as big as a millſtone.

The aurora borealis is another electrical phenomenon: this is admitted without any heſitation, becauſe electricians can readily imitate the appearance with their experiments.

James. It muſt be, I ſhould think, on a very ſmall ſcale.

Tutor. True: there is a glaſs tube about thirty inches long, and the diameter of it is about two inches; it is nearly exhauſted of air, and capped on both ends with braſs. I now connect theſe ends, by means of a chain, with the poſitive and negative part of a machine, and in a darkened room, you will ſee, when the machine is worked, all the appearances of the northern lights in the tube.

Charles. Why is it neceſſary nearly to exhauſt the tube?

Tutor. Becauſe the air, in its natural ſtate, is a very bad conductor of the electric fluid; but when it is, perhaps, rendered ſome hundred times rarer than it uſually is, the electric fluid darts from one cap to the other with the greateſt eaſe.

James. But we ſee the natural aurora borealis in the air.

Tutor. We do ſo, but it is in the higher regions of the atmoſphere, where the air is much rarer than it is near the ſurface of the earth. The experiment which you have juſt ſeen accounts for the darting and undulating motion which takes place between the oppoſite parts of the heavens. The aurora borealis is the moſt

beautiful and brilliant in countries in the high northern latitudes, as in Greenland and Iceland.

Charles. I remember the lines on this ſubject:

By dancing meteors then that ceaſeleſs ſhake,
A waving blaze refracted o'er the heavens,
And vivid moons and ſtars that keener play
With double luſtre from the gloſſy waſte,
Ev'n in the depth of polar night, they find
A wond'rous day; enough to light the chaſe,
Or guide their daring ſteps to Finland fairs.

Tutor. The aurora borealis that was ſeen in this country on the 23d of October, the preſent year, (1804) is deſerving of notice. At ſeven in the evening, a luminous arch was ſeen from the centre of London, extending from one point of the horizon,

about S. S. W. to another point N. N. W. and paſſing the middle of the conſtellation of the Great Bear, which it, in a great meaſure, obſcured. It appeared to conſiſt of ſhining vapour, and to roll from the ſouth to the north. In about half an hour its courſe was changed; it then became vertical, and about nine o'clock it extended acroſs the heavens from N. E. to S. W.; at intervals, the continuity of the luminous arch was broken, and there then darted from its ſouth-weſt quarter, towards the zenith, ſtrong flaſhes and ſtreaks of bright red, ſimilar to what appears in the atmoſphere during a great fire in any part of the metropolis. For ſeveral hours the atmoſphere was as light in the ſouth-weſt as if the ſun

had ſet but half an hour; and the light in the north reſembled the ſtrong twilight which marks that part of the horizon at Midſummer. Thomſon, ſpeaking of the aurora borealis, and other meteors, ſays

——————— Silent from the north,
A blaze of meteors ſhoots; enſweeping firſt
The lower ſkies, they all at once converge
High to the crown of heav'n, and all at once
Relapſing quick, as quickly re-aſcend,
And mix and thwart, extinguiſh and renew,
All æther courſing in a maze of light.

James. How do you account, ſir, for the Will-with-the-wiſp, or Jack-a-lanthorn, that is cloſe to the ground where the air is thickeſt?

Tutor. This is a meteor which ſeldom appears more than ſix feet

above the ground; it is always about bogs and ſwampy places, and theſe, in hot weather, emit what is called inflammable air, which is eaſily ſet fire to by the electric ſpark. Theſe, therefore, as you ſhall ſee in our chemical experiments, we can as readily imitate as the aurora borealis.—In ſome parts of Italy, meteors of this kind are frequently very large, and give a light equal to that of a torch.

Water-ſpouts, which are ſometimes ſeen at ſea, are ſuppoſed to ariſe from the power of electricity.

Charles. I have heard of theſe, but I thought that water-ſpouts at ſea, and whirlwinds and hurricanes by land, were produced ſolely by the force of the wind.

Tutor. The wind is, undoubtedly, one of the caufes, but it will not account for every appearance connected with them. Water-fpouts are often feen in calm weather, when the fea feems to boil, and fend up a fmoke under them, rifing in a fort of hill towards the fpout. A rumbling noife is often heard at the time of their appearance, which happens generally in thofe months that are peculiarly fubject to thunder ftorms, and they are commonly accompanied or followed by lightning. When thefe approach a fhip, the failors prefent and brandifh their fwords to difperfe them, which feems to favour the conclufion, that they are electrical.

James. Do the fwords act as conductors?

Tutor. They may, certainly; and it is known that by theſe pointed inſtruments they have been effectually diſperſed.

The analogy between the phenomena of water-ſpouts and electricity, may be made viſible by hanging a drop of water to a wire, communicating with the prime conductor, and placing a veſſel of water under it. In theſe circumſtances, the drop aſſumes all the various appearances of a water-ſpout, in its riſe, form, and mode of diſappearing.

Water-ſpouts, at ſea, are undoubtedly very like whirlwinds and hurricanes by land. Theſe ſometimes tear up trees, throw down buildings, make caverns; and in all the caſes they ſcatter the earth, bricks, ſtones, tim-

ber, &c. to a great diſtance in every direction. Dr. Franklin mentions a remarkable appearance which occurred to Mr. Wilke, a conſiderable electrician. On the 20th of July, 1758, at three o'clock in the afternoon, he obſerved a great quantity of duſt riſing from the ground, and covering a field, and part of the town in which he then was. There was no wind, and the duſt moved gently towards the eaſt, where there appeared a great black cloud, which electrified his apparatus poſitively to a very high degree. This cloud went towards the weſt, the duſt followed it, and continued to riſe higher and higher, till it compoſed a thick pillar, in the form of a ſugar loaf, and at length it ſeemed to be in con-

tact with the cloud. At some distance from this, there came another great cloud, with a long stream of smaller ones, which electrified his apparatus negatively, and when they came near the positive cloud, a flash of lightning was seen to dart through the cloud of dust, upon which the negative clouds spread very much, and dissolved in rain, which presently cleared the atmosphere.

Charles. Is rain then an electrical phenomenon?

Tutor. The most enlightened and best informed electricians reckon rain, hail, and snow, among the effects produced by the electric fluid.

James. Do the negative and positive clouds act in the same manner as the outside and inside coatings of a charged Leyden jar?

Tutor. Thunder-clouds frequently do nothing more than conduct or convey the electric matter from one place to another?

Charles. Then they may be compared to the difcharging rod?

Tutor. And perhaps, like that, they are intended to reftore the equilibrium between two places, one of which has too much, and the other too little of the electric fluid. The following is not an uncommon appearance: a dark cloud is obferved to attract others to it, and when grown to a confiderable fize, its lower furface fwells in particular parts towards the earth. During the time that the cloud is thus forming, flafhes of lightning dart from one part of it to the other, and often illuminate the whole mafs; and fmall clouds are obferved

moving rapidly beneath it. When the cloud has acquired a ſufficient extent, the lightning ſtrikes the earth in two oppoſite places.

James. I wonder the diſcharge does not ſhake the earth, as the charge of a jar does any thing through which it paſſes.

Tutor. Every diſcharge of clouds through the earth may do this, though it is imperceptible to us.

——————— Towers, temples, palaces,
Flung from their deep foundations roof on roof
Cruſhed horrible, and pile on pile o'erturn'd
Fall total,

MALLET.

Earthquakes are probably occaſioned by vaſt diſcharges of the electric fluid: they happen moſt frequently in dry and hot countries, which are ſubject to lightning, and other electric phenomena; they are even fore-

told by the electric corrufcations, and other appearances in the air for fome days preceding the event. Befides, the fhock of an earthquake is inftantaneous to the greateft diftances. Earthquakes are ufually accompanied with rain, and fometimes by the moft dreadful thunder-ftorms:

How greatly terrible, how dark and deep
The purpofes of heaven! At once o'erthrown,
White age and youth, the guilty and the juft,
Oh, feemingly fevere! promifcuous fall.
Reafon, whofe daring eye in vain explores
The fearful providence, confufed, fubdued
To filence and amazement, with due praife
Acknowledges th' Almighty, and adores
His will unerring, wifeft, jufteft, beft.

MALLET.

CONVERSATION XIV.

Medical Electricity.

TUTOR. If you ſtand on the ſtool with glaſs legs, and hold the chain from the conductor while I work the machine a few minutes, your pulſe will be increaſed, that is, it will beat more frequently than it did before. From this circumſtance phyſicians have applied electricity to the cure of many diſorders: in

ſome of which their endeavours have been unavailing, in others the ſucceſs has been very complete.

Charles. Did they do nothing more than this?

Tutor. Yes, in ſome caſes they took ſparks from their patients, in others they gave them ſhocks.

James. This would be no pleaſant method of cure if the ſhocks were ſtrong.

Tutor. You know by means of Lane's electrometer, deſcribed in our ſeventh Converſation, (Plate I. Fig. 10.) the ſhock may be given as ſlightly as you pleaſe.

Charles. But how are ſhocks conveyed through any part of the body?

Tutor. There are machines and apparatus made purpoſely for medical

purpofes, but every end may be anfwered by the inftrument juft referred to. Suppofe the electrometer to be fixed to a Leyden phial, and the knob at A to touch the conductor, and the knob B to be fo far off as you mean the fhocks to be weak or ftrong, one chain or wire is to be fixed to the ring C of the electrometer, and another wire or chain to the outfide coating: the other ends of thefe two wires are to be faftened to the two knobs of the difcharging rod.

James. What next is to be done if I wifh to electrify my knee for inftance?

Tutor. All you have to do is to bring the balls of the difcharging rod clofe to your knee, one on the one

ſide and the other on the oppoſite ſide.

Charles. And at every diſcharge of the Leyden jar, the ſuperabundant electricity from withinſide will paſs from the knob at A to the knob B, and will paſs through the wire and the knee, in its way to the outſide of the jar, to reſtore to both ſides an equilibrium.

James. But if it happen that a part of the body, as the arm, is to be electrified, how is it to be done, becauſe in that caſe I cannot uſe both my hands in conducting the wires?

Tutor. Then you may ſeek the aſſiſtance of a friend, who will, by means of two inſtruments called *directors*, be able to conduct the fluid to any part of the body whatever.

Charles. What are directors?

Tutor. A director consists of a knobbed brass wire, which, by means of a brass cap, is cemented to a glass handle. So the operator holding these directors by the extremities of the glass handle, brings the balls, to which the wires or chains are attached, into contact with the extremities of that part of the body of the patient through which the shock is to be sent. If I feel rheumatic pains between my elbow and wrist, and a person hold one director at the elbow and another about the wrist, the shocks will pass through, and probably will be found useful in removing the complaint.

James. Is it necessary to stand on

the glaſs-footed ſtool to have this operation performed?

Tutor. By no means: when ſhocks are adminiſtered, the perſon who receives them may ſtand as he pleaſes, either on the ſtool, or on the ground; the electric fluid taking the neareſt paſſage, will always find the other knob of the other director, which leads to the outſide of the jar.

Charles. Is it neceſſary to make the body bare?

Tutor. Not in the caſe of ſhocks, unleſs the coverings be very thick: but when ſparks are to be taken, then the perſon from whom they are drawn muſt be inſulated, and the cloaths ſhould be ſtripped off the part affected.

James. For what diforders are the fhocks and fparks chiefly ufed?

Tutor. Shocks have been found ufeful in paralytic diforders; in contractions of the nerves; in fprains, and in many other cafes; but great attention is neceffary in regulating the force of the fhock, becaufe, inftead of advantage, mifchief may occur if it be too violent.

Charles. Is there lefs danger with fparks?

Tutor. Yes; for unlefs it be in very tender parts, as the eye, there is no great rifk in taking fparks: and they have proved very effectual in removing many complaints.

The celebrated Mr. Fergufon was feized, at Briftol, with a violent fore

throat, ſo as to prevent him from ſwallowing any thing: he cauſed ſparks to be taken from the part affected, and in the courſe of an hour he could eat and drink without pain.

This is an excellent method in caſes of deafneſs, ear-ache, tooth-ache, ſwellings inſide the mouth, &c.

James. Would not ſtrong ſparks injure the ear?

Tutor. They might; and therefore the electric fluid is uſually drawn with a pointed piece of wood, to which it comes in a ſtream, or when ſparks are taken, a very ſmall braſs ball is uſed, becauſe, in proportion to the ſize of the ball, is the ſize of the ſpark.

CONVERSATION XV.

Of Animal Electricity: of the Torpedo: of the Gymnotus Electricus, and of the Silurus Electricus.

TUTOR. There are three kinds of fiſh which have been diſcovered that are poſſeſſed of the ſingular property of giving ſhocks very ſimilar to thoſe experienced by means of the Leyden jar.

Charles. I ſhould like much to ſee them; are they eaſily obtained?

Tutor. No, they are not: they are called the *torpedo*, the *gymnotus electricus*, and the *silurus electricus.*

James. Are they all of the same species?

Tutor. No: the torpedo is a flat fish, seldom twenty inches long, and is common in various parts of the sea coast of Europe. The electric organs of this fish are placed on each side of the gills, where they fill up the whole thickness of the animal, from the lower to the upper surface, and are covered by the common skin of the body.

Charles. Can you lay hold of the fish by any other part of the body with impunity?

Tutor. Not altogether so: for if it be touched with one hand, it ge-

nerally communicates a very ſlight ſhock; but if it be touched with both hands, at the ſame time, one being applied to the under, and the other to the upper ſurface of the body, a ſhock will be received ſimilar to that which is occaſioned by the Leyden jar.

James. Will not the ſhock be felt if both hands be put on one of the electrical organs at the ſame time?

Tutor. No: and this ſhows that the upper and lower ſurfaces of the electric organs are in oppoſite ſtates of electricity, anſwering to the poſitive and negative ſides of a Leyden phial.

Charles. Are the ſame ſubſtances conductors of the electric power of

the torpedo, by which artificial electricity is conducted?

Tutor. Yes they are: and if the fiſh, inſtead of being touched by the hands, be touched by conducting ſubſtances as metals, the ſhock will be communicated through them. The circuit may alſo be formed by ſeveral perſons joining hands, and the ſhock will be felt by them all at the ſame time. But the ſhock will not paſs where there is the ſmalleſt interruption; it will not even be conducted through a chain.

James. Can you get ſparks from it?

Tutor. No ſpark was ever obtained from the torpedo, nor could electric repulſion and attraction be produced by it.

Charles. Is it known how the power is accumulated?

Tutor. It ſeems to depend on the will of the animal, for each effort is accompanied with a depreſſion of its eyes, and it probably makes uſe of it as a means of ſelf-defence.

James. Is this the caſe alſo with the other electrical fiſhes?

Tutor. The *gymnotus* poſſeſſes all the electric properties of the torpedo, but in a very ſuperior degree. This fiſh has been called the electrical eel, on account of its reſemblance to the common eel. It is found in the large rivers of South America.

Charles. Are theſe fiſhes able to injure other fiſhes by this power?

Tutor. If ſmall fiſhes are put into the water in which the gymnotus is

kept, it will firſt ſtun, or perhaps kill them, and if the animal be hungry, it will then devour them. But fiſhes ſtunned by the gymnotus may be recovered, by being ſpeedily removed into another veſſel of water.

The gymnotus is ſaid to be poſſeſſed of a new kind of ſenſe, by which it knows whether bodies, which are brought near him, are conductors or not.

Charles. Then it poſſeſſes the ſame knowledge by inſtinct which philoſophers have gained by experiment.

Tutor. The following experiment, among others, is very deciſive on this point.

Ex. The extremities of two wires were dipped into the water of

the veſſel in which the animal was kept; they were then bent, extended a great way, and terminated in two ſeparate glaſſes full of water. Theſe wires, being ſupported by non-conductors, at a conſiderable diſtance from each other, the circuit was incomplete: but if a perſon put the fingers of both hands into the glaſſes in which the wires terminated, then the circuit was complete. While the circuit was incomplete, the fiſh never went near the extremities of the wires, as if deſirous of giving the ſhock; but the moment the circuit was completed, either by a perſon, or any other conductor, the gymnotus immediately went towards the wires, and gave the ſhock, though

the completion of the circuit was out of his fight.

James. How do they catch thefe kind of fifh; the men would, probably, let them go on receiving the fhock?

Tutor. In this way the property was, perhaps, firft difcovered. The gymnotus, as well as the others, may be touched, without any rifk of the fhock, with wax or with glafs; but if it be touched with the naked finger, or with a metal, or a gold ring, the fhock is felt up the arm.

Charles. Does the *filurus electricus* produce the fame effects as the others?

Tutor. This fifh is found in fome rivers in Africa, and it is known to

poſſeſs the property of giving the ſhock, but no other particulars have been detailed reſpecting it.

With regard to the torpedo, its power of giving the benumbing ſenſation was known to the ancients, and from this it probably took its name.—In Fermin's Natural Hiſtory of Surinam is ſome account of the *trembling-eel*, which Dr. Prieſtley conjectures to be different from the gymnotus; it lives in marſhy places, from whence it cannot be taken, except when it is intoxicated. It cannot be touched with the hand, or with a ſtick, without feeling a terrible ſhock. If trod upon with ſhoes, the legs and thighs are affected in a ſimilar manner.

CONVERSATION XVI.

General Summary of Electricity, with Experiments.

TUTOR. You now underſtand what electricity is?

Charles. Yes, it is a fluid which ſeems to pervade all ſubſtances, and when undiſturbed, it remains in a ſtate of equilibrium.

James. And that certain portion which every body is ſuppoſed to contain, is called its natural ſhare.

Tutor. When a body is poſſeſſed of more, or retains leſs than its natural ſhare, it is ſaid to be *charged* or electrified.

Charles. If it poſſeſs more than its natural ſhare, it is ſaid to be *poſitively* electrified, but if it contain leſs than its natural ſhare, it is ſaid to be *negatively* electrified.

Tutor. Does it not ſometimes happen, that the ſame ſubſtance is both poſitively and negatively electrified at the ſame time?

James. Yes: the Leyden jar is a ſtriking inſtance of this, in which, if the inſide contain more than its natural ſhare, the outſide contains leſs than its natural quantity.

Tutor. What is the diſtinction

between conductors and non-conductors of electricity?

Charles. The electric fluid paſſes freely through the *former*, but the *latter* oppoſe its paſſage.

Tutor. You know that electricity is excited in the greateſt quantities, by the friction of conducting and non-conducting ſubſtances againſt each other.

Ex. Rub two pieces of ſealing-wax, or two pieces of glaſs together, and only a very ſmall portion of electricity can be obtained, therefore the rubber of a machine ſhould be a conducting ſubſtance, and not inſulated.

Every electrical machine, with an inſulated rubber, will act in three different ways: the rubber will pro-

duce *negative* electricity: the conductor will give out *positive* electricity: and it will communicate both powers at once to a perſon or ſubſtance placed between two directors connected with them.

James. How does the rubber produce negative electricity?

Tutor. If you ſtand on a ſtool with glaſs legs, or upon any other non-conducting ſubſtance, and lay hold of the rubber, or a chain that communicates with it, the working the machine will take away from you a quantity of your natural electricity, therefore you will be negatively electrified.

Charles. Will this appear by the nature of the electric fluid, if I hold in my hand a ſteel point as a needle?

Tutor. If you, ſtanding on a non-conducting ſubſtance, are connected with the rubber, and your brother, in a ſimilar ſituation, connected with the conductor, hold points in your hands, and I, while I ſtand on the ground, firſt preſent a braſs ball, or other ſubſtance, to the needle in your hand, and then to that in his hand, the appearance of the fluid will be different in both caſes; to the needle in your hand it will appear like a ſtar, but to that in your brother's it will be rather in the form of a bruſh.—What will happen if you bring two bodies near to one another that are both electrified?

James. If they are both poſitively or both negatively electrified, they

will repel each other, but if one is negative and the other poſitive, they will attract one another till they touch, and the equilibrium is again reſtored.

Tutor. If a body, containing only its natural ſhare of electricity, be brought near to another that is electrified, what will be the conſequence?

Charles. A quantity of electricity will force itſelf through the air in the form of a ſpark.

Tutor. When two bodies approach each other, one electrified poſitively and the other negatively, the ſuperabundant electricity ruſhes violently from one to the other to reſtore the equilibrium. What will happen if your body, or any part of it, form part of the circuit?

James. It will produce an electric shock, and if, instead of one person alone, many join hands, and form a part of the circuit, they will all receive a shock at one and the same instant.

Tutor. If I throw a larger quantity of electricity than its natural share on one side of a piece of glass, what will happen to the other side?

Charles. The other side will become negatively electrified: that is, it will have as much less than its natural share, as the other has more than its natural share.

Tutor. Does electricity, communicated to glass, spread over the whole surface?

James. No, glass being an excellent non-conductor, the electric

fluid will be confined to the part on which it is thrown: and for that reaſon, and in order to apply it to the whole ſurface, the glaſs is covered with tin foil, which is called a *coating*.

Tutor. And if a conducting communication be made between both ſides of the glaſs, what takes place then?

Charles. A diſcharge; and this happens whether the glaſs be flat, or in any other form.

Tutor. What do you call a cylindrical glaſs veſſel thus coated for electrical purpoſes?

James. A Leyden jar; and when the inſides, and alſo the outſides of ſeveral of theſe jars are connected, it is called an electrical battery.

Tutor. Electricity, in this form, is capable of producing the most powerful effects, such as melting metals, firing spirits, and other inflammable substances —What effect has metallic points on electricity?

Charles. They discharge it silently, and hence their great utility in defending buildings from the dire effects of lightning.—Pray what is thunder?

Tutor. As lightning appears to be the rapid motion of vast masses of electric matter, so thunder is the noise produced by the motion of lightning: and when electricity passes through the higher parts of the atmosphere, where the air is very much rarefied, it constitutes the aurora borealis.

Ex. If two ſharp pointed wires be bent (Plate II. Fig. 29.) with the four ends at right angles, but pointing different ways, and they be made to turn upon a wire fixed on the conductor, the moment it is electrified, a flame will be ſeen at the points *a b c d*; the wire will begin to turn round in the direction oppoſite to that to which the points are turned, and the motion will become very rapid.

If the figures of horſes, cut in paper, be faſtened upon theſe wires, the horſes will ſeem to purſue one another, and this is called the electrical horſe-race. Of courſe, upon this principle, many other amuſing and very beautiful experiments may be made: and upon this principle

ſeveral electrical orreries have been contrived, ſhowing the motions of the earth and moon, and the earth and planets round the ſun.

James. How do you account for this?

Tutor. Fix a ſharp pointed wire into the end of the large conductor, and hold your hand near it:—no ſparks will enſue; but a cold blaſt will come from the point which will turn any light mills, wheels, &c.

GALVANISM.

CONVERSATION I.

Of Galvanifm; its Origin: Experiments: of the Decompofition of Water.

TUTOR. It has been obferved as long as I can remember, and probably before I was born, that porter, when taken from a pewter pot, had a fuperior flavour than when drunk out of a glafs or of china.

Charles. Yes, I have often heard my uncle fay fo, but what is the reafon of it?

Tutor. Admitting the fact, which is, I believe, generally allowed by those who are much accustomed to that beverage; it is now explained upon the principles of *Galvanism.*

James. Is Galvanism another branch of science? is there a Galvanic fluid as well as an electric fluid?

Tutor. Of the existence of the electric fluid you now have no doubt; the science of electricity took its name from *electron,* the Greek word for amber, because amber was one of the first substances observed to produce, by rubbing, the effects of attraction and repulsion. Galvanism derives its name from Dr. Galvani, who first reported to the philosophical

world the experiments on which the ſcience is founded.

Charles. Pray how was he led to make the experiments?

Tutor. Galvani, a profeſſor of anatomy at Bologna, was one evening making ſome electrical experiments, and on the table where the machine ſtood, were ſome frogs ſkinned: by an accident one of the company touched the main nerve of a frog, at the ſame moment that he took a conſiderable ſpark from the conductor of the electrical machine, and the muſcles of the frog were thrown into ſtrong convulſions. Theſe, which were obſerved by Galvani's wife, led the profeſſor to a number of experiments, but as they cannot be repeated without much cruelty to

living animals, I ſhall not enter into a detail of them.

James. Were not the frogs dead which firſt led to the diſcovery?

Tutor. Yes, they were: but the Profeſſor afterwards made many experiments upon living ones, whence he found that the convulſions, or as they are uſually called, the contractions produced on the frog, may be excited without the aid of any apparent electricity, merely by making a communication between the nerves and the muſcles with ſubſtances that are *conductors* of electricity.

Charles. Are theſe experiments peculiar to frogs?

Tutor. No, they have been ſucceſsfully made on almoſt all kinds of animals from the ox downwards to

the fly. And hence it was at firſt concluded, that there was an electricity peculiar to animals.

James. You have already ſhewn that the electric fluid exiſts in our bodies, and may be taken from them, independently of that which cauſes the contractions.

Tutor. I will ſhow you an experiment on this ſubject:—here is a thin piece of *zinc*, which is a ſort of metallic ſubſtance, but not what is denominated a perfect metal: lay it under your tongue, and lay this half crown upon the tongue; do you taſte any thing very peculiar in the metals?

James. No, nothing at all.

Tutor. Put them in the ſame poſition again, and now bring the

edges of the two metals into contact, while the other parts touch the under and upper surfaces of the tongue.

James. Now they excite a very disagreeable taste, something like copperas.

Tutor. Instead of the half crown, try the experiment with a guinea, or with a piece of charcoal.

Charles. I perceive the same kind of taste which James described. How do you explain the fact?

Tutor. Some philosophers maintain, that the principle of Galvanism and electricity is the same: and that the former is the evolution or emission of the electric fluid from *conducting* bodies, disengaged by a chemical process; while the latter is

the ſame thing made apparent to the ſenſes by *non-conducting* bodies.

James. All metals are conducting ſubſtances; of courſe the zinc, the guinea, and the half crown, are conductors.

Tutor. Yes, and ſo are the tongue and the ſaliva; and it is probable, that by the decompoſition of ſome ſmall particles of the ſaliva the ſharp taſte is excited.

Charles. What do you mean by the decompoſition of the ſaliva?

Tutor. We ſhall, in our chemiſtry, ſhew you that water is capable of being decompoſed, that is, ſeparated into two gaſſes called hydrogen and oxygen.

James. Is ſaliva capable of being thus ſeparated?

Tutor. Certainly, becaufe a great part of it may be fuppofed to be water; and the oxygen combines with the metal, while the hydrogen efcapes, and excites the tafte on the tongue.

Charles. The difagreeable tafte on the tongue cannot be difputed, but there is no apparent change on the zinc or the half-crown, which there ought to be if a new fubftance, as the oxygen, has entered into the combination.

Tutor. The change is, perhaps, too fmall to be perceived in this experiment: but in others on a larger fcale, it will be very evident to the fight, by the *oxidation* of the metals.

James. Here is another ftrange

word: I do not know what is meant by oxidation.

Tutor. The iron bars fixed before the window were clean and almoſt bright when placed there laſt ſummer.

James. But not being painted, they are become quite ruſty.

Tutor. Now in chemical language, the iron is ſaid to be oxidated inſtead of ruſty; and the earthy ſubſtance that may be ſcraped from them, uſed to be called the *calx* of iron; but it is, by modern chemiſtry, denominated the oxide of iron.

When mercury loſes its fine brightneſs by being long expoſed to the air, the dulneſs is occaſioned by oxidation, that is, the ſame effect is produced by the air on the mercury, as

it was on the iron. I will give you another inftance. I will melt fome lead in this ladle, you fee a fcum is fpeedily formed. I take it away, and another will arife, and fo perpetually till the whole lead is thus transformed into an apparently different fubftance; this is called the oxide of lead.

CONVERSATION II.

Galvanic Light, and Shocks.

CHARLES. We had a *taſte* of the Galvanic fluid yeſterday, is there no way of ſeeing it?

Tutor. Put this piece of zinc between the upper lip and the gums, as high as you can, and then lay a half crown, or guinea, upon the tongue, and when ſo ſituated bring the metals into contact.

Charles. I thought I ſaw a faint flaſh of light.

Tutor. I dare ſay you did, it was for that purpoſe I bid you make the experiment. It may be done in another way; by putting a piece of ſilver up one of the noſtrils, and the zinc on the upper part of the tongue, and then bring the metals in contact the ſame effect will be produced.

James. By continuing the contact of the two metals, the appearance of light does not remain.

Tutor. No, it is viſible only at the moment of making the contact. You may, if you make the experiment with great attention, put a ſmall ſlip of tin foil over the ball of one eye, and hold a tea-ſpoon in your mouth, and then upon the communication between the ſpoon and the tin a faint light will be viſible. Theſe

experiments are beſt performed in the dark.

Charles. Is there no means of making experiments on a larger ſcale?

Tutor. Yes, we have Galvanic batteries, as well as electrical batteries. Here is one of them. (Plate 11. Fig. 20.) It conſiſts of a number of pieces of ſilver, zinc, and flannel cloth, of equal ſizes, and they are thus arranged, a piece of zinc, a piece of ſilver, and a piece of cloth, moiſtened with a ſolution of ſalt in water, and ſo on till the pile is completed. To prevent the pieces from falling, they are ſupported on the ſides by three rods of glaſs ſtuck into a piece of wood, and down theſe rods

ſlides another piece of wood which keeps all the pieces in cloſe contact.

James. How do you make uſe of this inſtrument?

Tutor. Touch the lower piece of metal with one hand, and the upper one with the other.

James. I felt an electric ſhock.

Tutor. And you may take as many as you pleaſe; for as often as you renew the contact, ſo often will you feel the ſhock.

Here is a different apparatus (Plate II. Fig. 21.) in theſe three glaſſes (and I might uſe twenty inſtead of three) is a ſolution of ſalt and water. Into each, except the two outer ones, is plunged a ſmall plate of zinc, and another of ſilver. Theſe plates are made to communicate with each

other, by means of a thin wire, faſtened ſo that the ſilver of the firſt glaſs is connected with the zinc of the ſecond; the ſilver of the ſecond with the zinc of the third, and ſo on: now if you dip one hand into the firſt glaſs, and the other into the laſt, the ſhock is felt.

Charles. Will any kind of glaſſes anſwer for this experiment?

Tutor. Yes, they will; wine-glaſſes, or goblets, or finger-glaſſes; and ſo will china cups.

A third kind of battery, which is the moſt powerful, and the one that is moſt generally uſed is this. It conſiſts of a trough of baked wood, three inches deep, and about as broad. In the ſides of this trough are grooves oppoſite to each other,

and about a quarter of an inch aſunder. Into each pair of theſe grooves is put a plate of zinc, and another of ſilver, and they are to be cemented in ſuch a manner as to prevent any communication between the different cells. The cells are now filled with a ſolution of ſalt and water. The battery is complete; with your hands make a communication between the two end cells.

Charles. I felt a ſtrong ſhock.

Tutor. Wet your hands, and join your left with James's right, then put your right hand into one end cell, and let James put his left into the oppoſite one.

James. We both felt the ſhock like an electric ſhock, but not ſo ſevere.

Tutor. Several perſons may receive the ſhock together, by joining hands, if their hands are well moiſtened with water. The ſtrength of the ſhock is much diminiſhed by paſſing through ſo long a circuit. The ſhock from a battery conſiſting of fifty or ſixty pairs of zinc and ſilver, or zinc and copper, may be felt as high as the elbows. And if five or ſix ſuch batteries be united with metal cramps, the combined force of the ſhock would be ſuch that few would willingly take it a ſecond time.

Charles. What are the wires for at each end of the trough?

Tutor. With theſe a variety of experiments may be made upon combuſtible bodies. I will ſhew you

one with gunpowder, but I muſt have recourſe to four troughs united by cramps, or to one much larger than this.

Towards the ends of the wires are two pieces of glaſs tubes, theſe are for the operator to hold by, while he directs the wires. Suppoſe now four or more troughs united, and the wire to be at the two extremities, I put ſome gunpowder on a piece of flat glaſs, and then holding the wires by the glaſs tubes, I bring the ends of them to the gunpowder, and juſt before they touch, the gunpowder will be enflamed.

Inſtead of gunpowder, gold and ſilver leaf may be burnt in this

way: ether, ſpirits of wine, and other inflammable ſubſtances, are eaſily fired by the Galvanic battery; it will conſume even ſmall metallic wires.

Copper or braſs leaf, commonly called Dutch gold, burns with a beautiful green light, ſilver with a pale blue light, and gold with a yellowiſh green light.

James. Will the battery continue to act any great length of time?

Tutor. The action of all theſe kind of batteries is the ſtrongeſt, when they are firſt filled with the fluid; and it declines in proportion as the metals are oxidated, or the fluid loſes its power. Of courſe, after a certain time, the fluid muſt be changed and the metals cleaned, either with

ſand, or by immerſing them a ſhort time in diluted muriatic acid. The beſt fluid for filling the cells with, is water mixed with one tenth of nitrous acid. Care muſt always be taken to wipe quite dry the edges of the plates, to prevent a communication between the cells: and it will be found, that the energy of the battery is in proportion to the rapidity with which the zinc is oxidated.

CONVERSATION III.

Galvanic Conductors: Circles: Tables: Experiments.

TUTOR. You know that *conductors* of the electric fluid differ from each other in their conducting power.

Charles. Yes, the metals were the most perfect conductors, then charcoal, afterwards water and other fluids. See Vol. VI, p. 20.

Tutor. In Galvanism we call the former *dry* and *perfect* conductors,

these are the first class: the latter, or second class, *imperfect* conductors: and in rendering the Galvanic power sensible, the combination must consist of three conductors of the different classes.

James. Do you mean two of the first class, and one of the second?

Tutor. When two of these bodies are of the first class, and one is of the second, the combination is said to be of the *first order.*

Charles. The large battery which you used yesterday was of the *first order* then, because there were two metals, viz. zinc and silver, and one fluid.

Tutor. This is called a *simple Galvanic circle,* the two metals touched each other in some points, and at

other points they were connected by the fluid which was of the different clafs.

James. Will you give us an example of the fecond order?

Tutor. When a perfon drinks porter from a pewter mug, the moifture of his under lip is one conductor of the fecond clafs, the porter is the other, and the metal is the third body, or conductor of the firft clafs.

The difcoloration of a filver fpoon, in the act of eating eggs, is a Galvanic operation. A fpoon merely immerfed in the egg undergoes no difcoloration, it is the act of eating that produces the change. This is a Galvanic combination of the fecond order, the fluid egg, and the

faliva, are fubftances of the fecond clafs of conductors, and the filver of the firft clafs.

Charles. Which are the moft powerful Galvanic circles?

Tutor. They are thofe of the firft order, where two folids of different degrees of oxidability are combined with a fluid capable of oxidating at leaft one of the folids. Thus gold, filver, and water, do not form an active Galvanic circle, but it will become active if a little nitric acid, or any fluid decompofible by filver, be mixed with the water. An active Galvanic circle is formed of zinc, filver, and water, becaufe the zinc is oxidated by water. But a little nitric acid, added to the water,

renders the combination ſtill more active, as the acid acts upon the ſilver and the zinc.

The moſt powerful Galvanic combinations of the ſecond order are, where two conductors of the ſecond claſs have different chemical actions on the conductors of the firſt claſs, at the ſame time that they act upon each other. Thus copper, ſilver, or lead, with a ſolution of an alkaline ſulphuret* and diluted nitrous acid, form a very active Galvanic circle. Hence the following

* If equal quantities of ſulphur and alkali be melted in a covered crucible, the maſs obtained is called an alkaline ſulphuret.

Table of Galvanic circles of the *first order*, composed of two perfect conductors, and one imperfect conductor.

Very Oxydable Substances.	Less Oxidable Substances.	Oxidating Fluids.
Zinc - -	With gold, charcoal, silver, copper, tin' iron, mercury	Solutions of nitric acid in water, of muriatic acid, and sulphuric acid, &c. Water holding in solution oxygene atmospheric air, &c.
Iron - -	With gold, charcoal, silver, copper, tin	
Tin - -	With gold, silver, charcoal	
Lead - -	With gold, silver	
Copper -	With gold, silver	Solution of nitrate of silver, and mercury, nitric acid, acetous acid.
Silver - -	With gold	Nitric acid.

Table of Galvanic circles of the *second order*, composed of two imperfect conductors, and one perfect conductor.

Perfect Conductors.	Imperfect Conductors.	Imperfect Conductors.
Charcoal Copper - Silver - Lead - - Tin - - Iron - - Zinc - -	Solutions of hydrogenated alkaline sulphurets, capable of acting on the first three metals, but not on the last three.	Solution of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.

I will now shew you another experiment which is to be made with the assistance of the great battery (Fig. 22.) A B (Plate II. Fig. 23.) exhibits a glass tube filled with distilled water, and having a cork at each end. A and B are two pieces of brass wire, which are brought to within an inch or two of one an-

other in the tube, and the other ends are carried to the battery, viz. A to what is called the poſitive end, and B to the negative end.

James. You have then poſitive and negative Galvaniſm as well as electricity?

Tutor. Yes, and if the circuit be interrupted, the proceſs will not go on. But if all things be as I have juſt deſcribed, you will ſee a conſtant ſtream of bubbles of gas proceed from the wire B, which will aſcend to the upper part of the tube. This gas is found to be hydrogen or inflammable air.

Charles. How is that aſcertained?

Tutor. By bringing a candle cloſe to the opening when I take out the

cork A, the gas will immediately inflame. The bubbles which proceed from the wire A are oxygen or pure air, they accumulate and ſtick about the ſides of the tube.

James. How is this experiment explained?

Tutor. It is believed that the water is decompoſed or divided into hydrogen and oxygen: the hydrogen is ſeparated from the water by the wire connected with the negative extremity, while the oxygen unites with and oxidates the wire connected with the poſitive end of the battery.

If I connect the poſitive end of the battery with the lower wire, and the negative with the upper, then

the hydrogen proceeds from the upper wire, and the lower wire is oxidated.

If wires of gold or platina be used which are not oxidable, then a stream of gas issues from each, which may be collected, and will be found to be a mixture of hydrogen and oxygen.

Charles. Are there no means of collecting these fluids separately?

Tutor. Yes, instead of making use of the tube, let the extremities of the wires, which proceed from the battery, be immersed in water, at the distance of an inch from each other, then suspend over each a glass vessel, inverted and full of water, (Plate 11. Fig. 24.) and the dif-

ferent kinds of gas will be found in the two glaſſes.

It is known that hydrogen gas reduces the oxides of metals, that is, reſtores them to their metallic ſtate. If, therefore, the tube (Fig. 23.) be filled with a ſolution of acetite of lead* in diſtilled water, and a communication is made with the battery, no gas is *perceived* to iſſue from the wire, which proceeds from the *negative* end of the battery, but in a few minutes, beautiful metalic needles may be ſeen on the extremity of this wire.

James. Is this the lead ſeparated from the fluid?

* Acetite of lead, is a ſolution of lead in acetous acid.

Tutor. It is, and you perceive it is in a perfect metallic ſtate, and very brilliant. Let the operation proceed, and theſe needles will aſſume the form of fern, or ſome other vegetable ſubſtance.

The ſpark from a Galvanic battery acts with wonderful activity upon all inflammable bodies, and experiments made in a dark room, upon gunpowder, charcoal, metallic wire, and metallic leaves, &c. may be made very amuſing.

CONVERSATION IV.

Miſcellaneous Experiments.

TUTOR. The diſcoveries of Galvani were made principally with dead frogs; from his experiments, and many others that have been made ſince his time, it appears that the *nerves of animals* may be affected by ſmaller quantities of electricity than any other ſubſtances with which we are acquainted. Hence limbs of animals, properly prepared, have been

much employed for aſcertaining the Galvanic electricity.

Charles. What is the method of preparation?

Tutor. I have been cautious in mentioning experiments on animals, leſt they ſhould lead you to trifle with their feelings; I muſt, however, to render the ſubject more complete, tell you what has been done.

The muſcles of a frog lately dead, and ſkinned, may be brought into action by means of very ſmall quantities of common electricity.

If the leg of a frog recently dead be *prepared*, that is, ſeparated from the reſt of the body, having a ſmall portion of the ſpine attached to it, and ſo ſituated that a little electricity

may paſs through it, the leg will be inſtantly affected with a kind of ſpaſmodic contraction, ſometimes ſo ſtrong as to jump a conſiderable diſtance.

It is now known that ſimilar effects may be produced in the limb thus *prepared*, by only making a communication between the nerves and the muſcles by a conducting ſubſtance. Thus, in an animal recently dead, if a nerve be detached from the ſurrounding parts; and the coverings be removed from over the muſcles which depend on that nerve; and if a piece of metal, as a wire, touch the nerve with one extremity, and the muſcle with the other, the limb will be convulſed.

Charles. Is it neceſſary that the communication between the nerve and the muſcle ſhould be made with a conducting ſubſtance?

Tutor. Yes, it is: for if ſealing-wax, glaſs, &c. be uſed inſtead of metals, no motion will be produced.

If part of the nerve of a *prepared* limb be wrapped up in a ſlip of tin foil, or be laid on a piece of zinc, and a piece of ſilver be laid with one end upon the muſcle, and with the other on the tin or zinc, the motion of the limb will be very violent.

Here are two wine-glaſſes almoſt full of water; and ſo near to each other as barely not to touch: I put the *prepared* limb of the frog into one glaſs, and lay the nerve, which is wrapped up in tin foil, over the edges

of the two glaſſes, ſo that the tin may touch the water of the glaſs in which the limb is not. If I now form a communication between the water in two glaſſes, by means of ſilver, as a pair of tea tongs; or put the fingers of *one* hand into the water of the glaſs that contains the leg, and hold a piece of ſilver in the other, ſo as to touch the coating of the nerves with it, the limb will be immediately excited, and ſometimes when the experiment is well made, the leg will even jump out of the glaſs.

James. It is very ſurprizing that ſuch kind of motions ſhould be produced in dead animals.

Tutor. They may be excited alſo in living ones: if a live frog be placed on a plate of zinc, having a

ſlip of tin foil upon its back, and a communication be made between the zinc and tin foil, by a piece of metal, as ſilver, the ſame kind of contractions will take place.

Charles. Can this experiment be made without injury to the animal?

Tutor. Yes, and ſo may the following: I take a live flounder and dry it with a cloth, and then put it in a pewter plate, or upon a large piece of tin foil, and place a piece of ſilver on its back; I now make a communication between the metals with any conducting ſubſtance, and you ſee the contractions, and the fiſh's uneaſineſs. The fiſh may now be replaced in water.

I place this leech on a crown piece, and then, in its endeavour to

move away, let it touch a piece of zinc with its mouth, and you will ſee it inſtantly recoil, as if in great pain: the ſame thing may be done with a worm.

It is believed that all animals, whether ſmall or great, may be affected, in ſome ſuch manner, by Galvaniſm, though in different degrees.

The limbs of people, while undergoing the operation of amputation, have been convulſed by the application of the inſtruments, an effect which is eaſily explained by Galvaniſm.

By the knowledge already obtained in this ſcience, the following facts are readily explained.

Pure mercury retains its metallic ſplendor during a long time; but its

amalgam with any other metal is ſoon tarniſhed or oxidated.

Ancient inſcriptions, engraved upon pure lead, are preſerved to this day, whereas ſome medals compoſed of lead and tin, of no great antiquity, are very much corroded.

Works of metal, whoſe parts are ſoldered together by the interpoſition of other metals, ſoon oxidate about the parts where the different metals are joined. And there are perſons who profeſs to find out ſeams in braſs and copper veſſels by the tongue, which the eye cannot diſcover, and they can, by this means, diſtinguiſh the baſe mixtures which abound in gold and ſilver trinkets.

When the copper ſheeting of ſhips is faſtened on by means of iron nails,

thoſe nails, but particularly the copper, are very quickly corroded about the place of contact.

A piece of zinc may be kept in water a long time, without ſcarcely oxidating at all; but the oxidation takes place very ſoon if a piece of ſilver touch the zinc, while ſtanding in the water.

If a cup made of zinc or tin be filled with water, and placed upon a ſilver waiter, and the tip of the tongue be applied to the water, it is found to be inſipid; but if the waiter be held in the hand, which is well moiſtened with water, and the tongue applied as before, an acid taſte will be perceived.

Charles. Is that owing to the cir-

cuit being made complete by the wet hand?

Tutor. It is; another experiment of a ſimilar kind is the following: If a tin baſon be filled with ſoap-ſuds, lime-water, or a ſtrong ley, and then the baſon be held in both hands, moiſtened with pure water, while the tongue is applied to the fluid in the baſon, an *acid* taſte will be ſenſibly perceived, though the liquor is *alkaline.*

From this ſhort account of Galvaniſm it may be inferred:—

(1.) That it appears to be only another mode of exciting electricity.

(2.) Galvanic electricity is produced by the chemical action of bodies upon each other.

(3.) The oxidation of metals appears to produce it in great quantities.

(4.) Galvanic electricity can be made to set inflammable substances on fire, to oxidate and even inflame metals.

(5.) The nerves of animals appear to be most easily affected by it of any known substances.

(6.) Galvanic electricity is conducted by the same substances as common electricity.

(7.) When it is made to pass through an animal, it produces a sensation resembling the electrical shock.

(8.) The electricity produced by the torpedo and electrical eel is very similar to Galvanism.

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Immerſe, to plunge in.

Impel, to drive on.

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Incompreſſible, not capable of being preſſed into a ſmaller compaſs.

Inertia, of matter, its tendency to continue in the ſtate in which it is.

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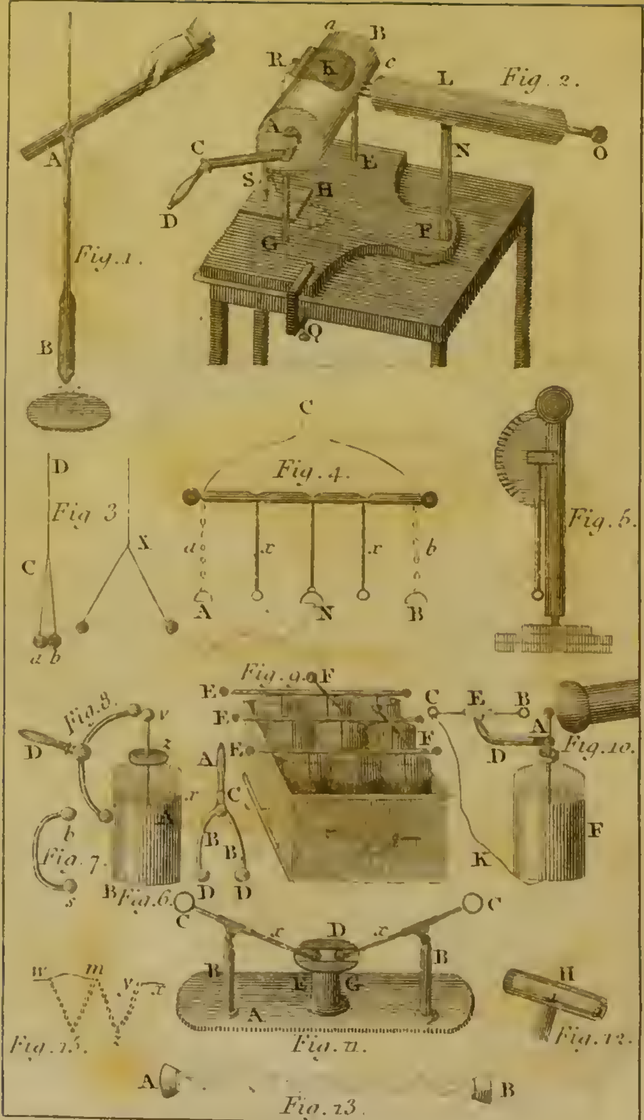

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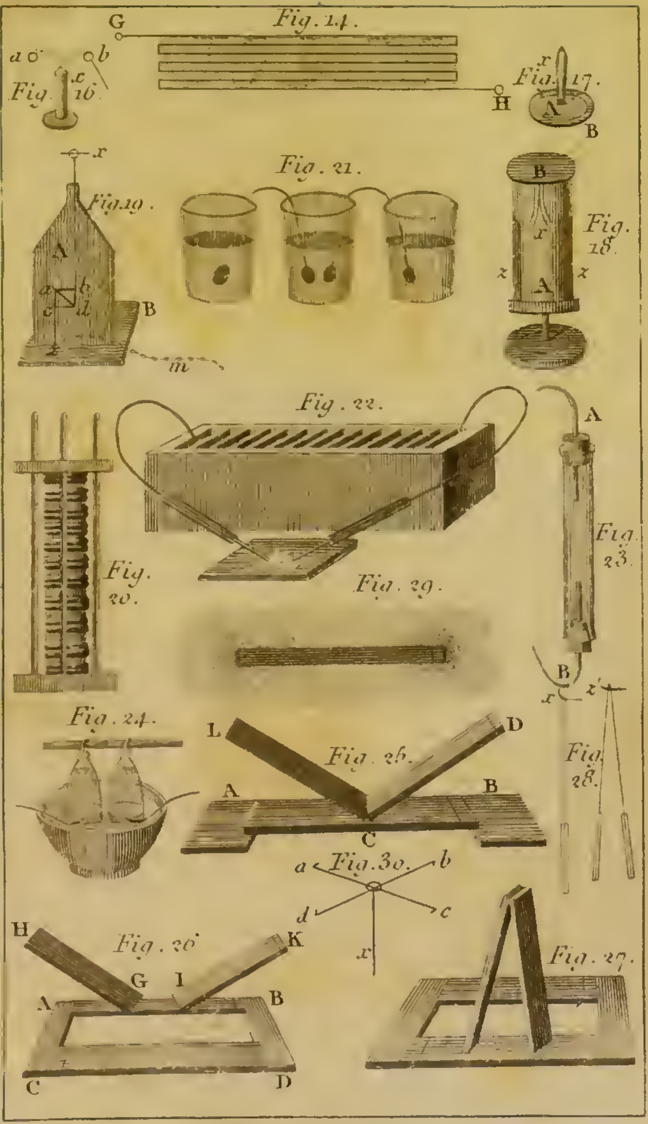

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